PART D OPERATIONAL SUPPORT EQUIPMENT

VOYAGER CAPSULE BUS SYSTEM

PREPARED FOR:
CALIFORNIA INSTITUTE OF TECHNOLOGY
JET PROPULSION LABORATORY
PASADENA, CALIFORNIA
CONTRACT NUMBER 952000

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MCDONNELL ASTRONAUTICS

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REPORT ORGANIZATION

VOYAGER PHASE B FINAL REPORT

The results of the Phase B Voyager Flight Capsule study are organized into several volumes. These are:

Volume I Summary

Volume II Capsule Bus System

Volume III Surface Laboratory System

Volume IV Entry Science Package

Volume V System Interfaces

Volume VI Implementation

This volume, Volume 11, describes the McDonnell Douglas preferred design for the Capsule Bus System. It is arranged in 5 parts, A through E, and bound in 11 separate documents, as noted below.

Part A	Preferred Design Concept	2 documents, Parts A_1 and A_2
Part B	Alternatives, Analyses, Selection	5 documents, Parts B ₁ ,
		B_2 , B_3 , B_4 and B_5
Part C	Subsystem Functional Descriptions	2 documents, Parts C ₁
		and C_2
Part D	Operational Support Equipment	1 document
Part E	Reliability	1 document

In order to assist the reader in finding specific material relating to the Capsule Bus System, Figure 1 cross indexes broadly selected subject matter, at the system and subsystem level, through all volumes.

VOLUME II CROSS REFERENCE INDEX

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		MISSION, DESIGN,	METHODS TRADE	FUNCTIONS	TEM, LAUNCH COM-	GRAM TESTING,
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0.S.E. (Se.	O.S.E. (See Also Part D)	8-General	(See D2.5-Selection	(See D5-Subsystem	Complete OSE	(See D4.3.6-STC D4.4.6-LCE
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SUMMARY

The Operational Support Equipment (OSE) concept is based on a systems—oriented analysis of the VOYAGER program requirements and capsule OSE guidelines and constraints. OSE is a vital element in achieving a successful VOYAGER mission. OSE, flight systems, and test concepts are balanced to provide a Capsule Bus OSE design which meets program objectives and requirements.

- o <u>Probability of Mission Success</u> Our approach to Operational Support Equipment for the Capsule Bus maximizes the probability of mission success and launch-on-time by using the speed, repeatability, and safety of computer controlled checkout, while retaining man-in-the-loop for critical decision making and contingency action. The repeatability of automated testing provides a high confidence test data bank with rapid access to diagnostic and trend analysis data during ground test and mission operations.
- o <u>Planetary Quarantine</u> Integration of system test requirements into the design of our flight telemetry and in-flight checkout systems has solved the problem of transmitting system test data through the Capsule sterile canister, and has led to the development of a System Test Complex which can conduct system level tests at KSC with minimum dependence on Subsystem Test Sets.
- Systems Computer to perform automatic test sequencing, response analysis, automatic limit and alarm monitoring, data suppression, and OSE self-check. Major elements of the SIC include the Subsystem Test Consoles, Test Conductor's Console, Computer Data System, Ground Data Transmission System, and Communication, Timing, and Power Distribution Groups. The capability of the Subsystem Consoles to accomplish Capsule Bus integrated test without the use of Subsystem Test Sets provides maximum scheduling flexibility with reduced total OSE quantity and cost, requires less space for integrated operations at KSC, and is compatible with the use of Apollo Acceptance Checkout Equipment (ACE) and facilities at KSC. Integration of the Capsule Bus OSE with the Spacecraft, SLS, Mission Operations System, and other VOYAGER System elements is reflected in our selected design interfaces, OSE arrangement, and data link utilization.

- o <u>Subsystem Test Concept</u> Subsystem Test Sets (SSTS) are automated on selected subsystems for which it represents a cost-effective solution:

 Telemetry, Guidance and Control, Sequencer, and Radar. Small automatic processors provide flexibility to accommodate flight system changes and capacity for independent subsystem tests, and are compatible with future growth to centralized computer control. SSTS and STC feature extensive use of digital displays for high accuracy and reduction of human error. A hard copy printout provides a permanent record of test completion and acceptance. Manually controlled Subsystem Test Sets are provided for Power, Propulsion, Pyrotechnic, and Thermal subsystems.
- o Launch Pad Operations A Capsule Bus Launch Monitor Console located in the Launch Control Center is hardlined to associated Launch Complex Equipment (LCE) at the Launch Pad for maximum reliability in safeing the Capsule if a critical malfunction occurs. Use of the Spacecraft umbilical for the LCE hardlines eliminates use of the Capsule Bus umbilical for launch pad operations. The Capsule Bus System Test Complex provides automatic monitoring and alarm backup for the Launch Complex Equipment.
- o <u>Mission Dependent Equipment</u> Capsule Bus Mission Dependent Equipment consists of software and telemetry processing equipment required for decommutation, coding, command encoding, and telemetry processing in the Deep Space Instrumentation Facility, and diagnostic displays used in the Space Flight Operations Facility. Identical software is used to perform telemetry decommutation in the System Test Complex, thus reducing hardware requirements.
- o OSE Development OSE Development risk is minimized by extensive utilization of proven hardware and standardized computer software. Phased "building-block'' software development provides maximum commonality of software packages, and assures early use of the computer for manual mode operation prior to validation of test software. Equipment modules are standardized for commonality of design, spares, and field support.
- o <u>Utilization and Human Factors</u> The Capsule Bus OSE is designed and configured for compatibility with the test team approach used successfully on previous interplanetary and McDonnell-Douglas spacecraft programs.

A test team composed of cognizant flight subsystem engineers and experienced test, launch, and mission operations personnel is assigned to a particular capsule from factory operations through launch and mission operations.

Major studies conducted as part of OSE concept selection include alternative methods of automation, display techniques, computer utilization, and transportation methods. Supporting data includes an analysis of an alternative OSE integration concept, based on maximum sharing of equipment by CB or SLS contractors.

The selected OSE concept meets the VOYAGER program objectives and requirements, provides operational flexibility and program growth potential, and is designed for realistic implementation.

SECTION 1

INTRODUCTION AND OBJECTIVES

1.1 INTRODUCTION - This volume contains the functional descriptions and preliminary designs of the recommended Operational Support Equipment (OSE) and Mission Dependent Equipment (MDE) for the Capsule Bus System. The approach used to establish the OSE requirements, translation of these requirements into design criteria, identification of alternative design and utilization concepts, and the rationale and criteria employed in selection of the preferred concept are described. Trade studies and supporting data are included.

Operational Support Equipment (OSE) for the Capsule Bus System includes all ground-based equipment and software required to test, checkout, transport, handle, align, install, and service the Capsule Bus from factory through launch, and the equipment and software (MDE) required to interface the Flight Capsule with the existing and planned facilities of the Deep Space Network. Additionally, CBS OSE includes Capsule Bus Simulators required at the Spacecraft and SLS contractor facilities and government furnished equipment required for SLS integration at the CB contractor's facility.

- 1.2 VOYAGER PROGRAM AND MISSION OBJECTIVES The ultimate goal of Capsule OSE is to provide the maximum probability of on-schedule accomplishment of VOYAGER's scientific mission, and successful acquisition of the mission data. In addition, Capsule Bus OSE must provide "The assurance of some measure of success, regardless of circumstances." Recognizing the vital role of Operational Support Equipment and Mission Dependent Equipment in attaining these goals, we have established fundamental objectives for the performance, integration, development, and implementation of Capsule Bus OSE, based upon VOYAGER program studies and our Mercury/Gemini experience.
- 1.3 CAPSULE BUS OSE OBJECTIVES -
- 1.3.1 Performance and Design Objectives
 - o Provide the highest practical probability of launch-on-time. Key to attainment of this objective is the reliability, speed, and availability of the OSE used for prelaunch and launch operations at KSC.
 - o Accurately and repeatably detect and/or isolate all capsule and OSE malfunctions.

- o Provide test continuity, elimination of test variables and a continuous test history as the capsule and its components flow from factory through launch and mission operations.
- o Protect personnel, flight systems, and OSE from hazard or damage due to OSE failure or human error.
- o Achieve maximum commonality of functional modules and utilization of common design.
- o Accommodate subsystem changes and provide growth potential and flexibility for future missions with minimum change.

1.3.2 <u>Integration Objectives</u>

- o Clearly define the physical and functional interfaces of Capsule OSE and provide the minimum duplication of equipment consistent with clear-cut contractual responsibility.
- o Maximize compatibility with existing facilities at KSC, and with other elements of the VOYAGER System.
- o Design and package OSE to conserve space in integrated operations areas.
- o Incorporate effective and economical maintainability provisions to insure the operational availability of the OSE.

1.3.3 <u>Development and Implementation Objectives</u>

- o Minimize development risk by maximum use of OSE designs and off-theshelf components which have proven performance on the Mariner, Lunar Orbiter, Gemini, and other NASA programs. Use existing hardware where consistent with performance requirements.
- o Demonstrate OSE and software compatibility with the Capsule, SLS, Space-craft, and DSIF prior to acceptance test of the first flight vehicle.
- o Employ practical. cost solutions to optimize the cost-effectiveness ratio of Capsule Bus OSE.

SECTION 2

REQUIREMENTS AND CONSTRAINTS

Successful implementation of the VOYAGER program requires more than compliance with the specified requirements alone. We have analyzed the significiant problems presented by Capsule Bus configuration, sterilization, and integrated checkout in order to derive the additional requirements that will contribute the extra performance margin necessary to assure VOYAGER mission success. This section describes the basic Flight Capsule Operational Support Equipment (OSE) requirements and constraints, and the McDonnell derived requirements used in developing the Capsule Bus OSE design concept.

- 2.1 Basic Requirements and Applicable Documents The Capsule Bus OSE requirements and constraints contained in the documents listed below are the basic JPL requirements used in the development of our concepts and in our OSE design.
 - a. MA003BB00**2-2**A11 File MA3AA7E005 "Guidelines for the Voyager Capsule Contractor" dated 18 May 1967 (Revision 1)
 - b. SE003BB002-2A21, File SE3BC-7E-004, "1973 Voyager Capsule Systems

 Constraints and Requirements Document" dated 18 May 1967 (Revision 1)
 - c. SE002BB001-1B21, File SE1DC, "Performance and Design Requirements for the 1973 Voyager Mission, General Specifications for", dated 1 January 1967
 - d. RFP V06-4509 Enclosure 2, "Voyager Capsule Specimen Statement of Work Phase B", modified by JPL TWX 1921252, dated May 1967
 - e. Engineering Planning Document #283, Revision 2, "Planned Capabilities of the DSN for Voyager 1973", dated 1 January 1967
 - f. Technical Memorandum #33-255, "Description of the Deep Space Network Operational Capabilities as of January 1, 1966", dated 1 July 1966
 - z. AEIRM 127-1 Range Safety Manual No. 1, dated 10 September 1965
- 2.2 Constraints The most significant customer constraints are:
 - a. Time-limited launch opportunity, launch window, and launch period.
 - b. Complex 39 will be used as Kennedy Space Center
 - c. Planetary quarantine requirements must not be degraded
 - d. Two planetary vehicles will be launched on a single launch vehicle
- 2.3 Derived Requirements Capsule Bus OSE Using the OSE objectives and the basic JPL requirements and constraints as a foundation, additional OSE requirements have been derived by analysis of the problem areas, Capsule Bus (CB) flight subsystems, test requirements, the integrated test plan and other VOYAGER

System's integration requirements. The derived Capsule Bus OSE requirements are as follows:

- a. Mission critical OSE must be allocated a Ps based on reliability analysis of launch operation and supporting equipment. Mission critical OSE is defined as that equipment or software, (including Mission Dependent Equipment) whose failure could delay or abort a launch during the terminal count or cause degradation of the mission after launch.
- b. After encapsulation of the Flight Capsule in the canister, the Flight Capsule STC must be capable of performing integrated system tests, fault isolation, and monitoring critical parameters.
- c. OSE required inside the Class 100 Rooms must be designed for minimum contamination of the Capsule Bus and Class 100 environment.
- d. LCE must provide fault isolation and decision-making capability to the level required for launch commitment.
- e. Subsystem OSE must be designed for performance margin testing and provide a historical data base readily correlated with system test data after flight Capsule encapsulation.
- f. Trend analysis and failure mode prediction data must be recorded during tests.
- g. The System Test Complex (STC) must be capable of monitor and checkout of two Capsule Buses on the Pad and be available for periodic checkout of two Capsule Buses in storage.
- h. Human engineering must be performed on all OSE designs to determine the best method of displaying information and arrangement of controls in order to minimize operator error and provide maximum safety for personnel and equipment.
- 2.4 Derived Requirements (SLS) and Spacecraft (SC) Contractor OSE
 - a. During Planetary Vehicle (PV) systems test and launch pad operations, the SC Contractor's STC must strip out and reroute Capsule Bus TM data to the Capsule Bus System Test Complex (STC).
 - b. The SC Contractor's flyaway umbilical must contain an adequate number of pins for handling critical signals and RF coax-connectors for launch pad operations.
 - c. The SLS Contractor must provide test point access for analysis and fault isolation during Flight Capsule integration and environmental testing.

- d. The SC and SLS Contractors must provide interface simulators which precisely simulate signals and loads for checking compatibility prior to mate.
- 2.5 OSE Baseline Integration Requirement In order to comply with the Statement of Work Request to provide separate volumes, we have treated the CBS, SLS, & ESP as separate systems and identified the requirements and OSE separately for each system. This approach isolates the support requirements for each system and establishes a point of reference for objective integration of OSE functions when the systems configuration and technical responsibility have been established. However, in order to provide VOYAGER Management further insight into the full potential of sharing common OSE during integrated operations, we have included a study of such an alternative integration concept in Section 10.
- 2.6 Selection Criteria Selection of our design concept has been accomplished by weighing alternative design approaches against selection criteria developed in accordance with VOYAGER objectives. Major OSE selection criteria are summarized below and described in detail in Section 10.0.
 - a. Probability of Mission Success (OSE reliability and operational availability)
 - OSE and Flight System Performance (Test quality, test time, test confidence)
 - c. Development and Schedule Risk (Initial OSE availability and contingency potential)
 - d. Versatility/Flexibility (OSE growth potential, common usage)
 - e. Cost (OSE Hardware, Maintenance, development and operating costs)

SECTION 3

PREFERRED APPROACH - OPERATIONAL SUPPORT EQUIPMENT (OSE)

This section summarizes the utilization, design, and operating characteristics of the major OSE systems, and the major trade studies and criteria involved in selection of our concept. Complete preliminary designs, functional descriptions, and supporting analyses are provided in Sections 4 through 10, Part D.

- 3.1 OSE UTILIZATION CONCEPT Capsule Bus (CB) OSE is designed to support development and flight acceptance testing from factory through launch. During the mission and landed Mars operations, Mission Dependent Equipment (MDE) provides continued operational support. Because OSE design is so fundamentally dependent upon supporting these operations, a summary of OSE utilization is presented as an orientation and introduction to the design concept.
- 3.1.1 OSE Catepories and Functions The basic OSE categories and their functions are in accordance with the JPL constraints document, and as further defined below:

 Subsystem Test Equipment (SSTE) Test equipment related primarily to the testing of a particular flight subsystem. For the CB, SSTE is composed of Subsystem Test Sets and Subsystem Test Consoles. The Subsystem Test Sets (SSTS) are used for pre-delivery acceptance (PDA) of modules at principal subsystem vendors; at the CB contractor's factory for Equipment Functional Check (EFC) of delivered flight hardware prior to capsule installation, and for subsystem level tests during module and capsule buildup. Propulsion, and Pyrotechnic and certain SLS SSTS are used at RSC on a scheduled basis; the balance of SSTS is required at KSC on a contingency basis only. The Subsystem Test Consoles are used for integrated CB System tests, as described below.

System Test Complex (STC) - Equipment used for integrated system tests and simulated missions at the CB contractor's factory and KSC. Also used for Launch Complex Equipment (LCE) functions to reduce quantity of LCE required. STC consists of selected items of SSTE plus OSE system elements. Subsystem Test Equipment (SSTE) used exclusively for integrated CB System tests, such as Subsystem Test Consoles, will be carried in the STC category to conform with their primary functional OSE system's interface.

<u>Launch Complex Equipment (LCE)</u> - Supplements the STC for control and monitor of operations on the launch pad and at the KSC Explosive Safe Facility (ESF). Provides power, alarm warning, and emergency control of the capsule prior to launch.

Mission Dependent Equipment (MDE) - Used to conduct operations from the Deep Space Network (DSN) and Space Flight Operations Facility (SFOF) during cruise, entry and after landing on Mars. Also used in the STC to establish compatibility between capsule bus telemetry and the Deep Space Instrumentation Facility (DSIF) at KSC, and to perform telemetry processing.

<u>Spacecraft Mounted Capsule Bus Support Equipment OSE (SCME)</u> - Used at the Spacecraft Contractor's plant for subsystem testing of capsule bus hardware installed in the spacecraft, and in the STC for integrated tests.

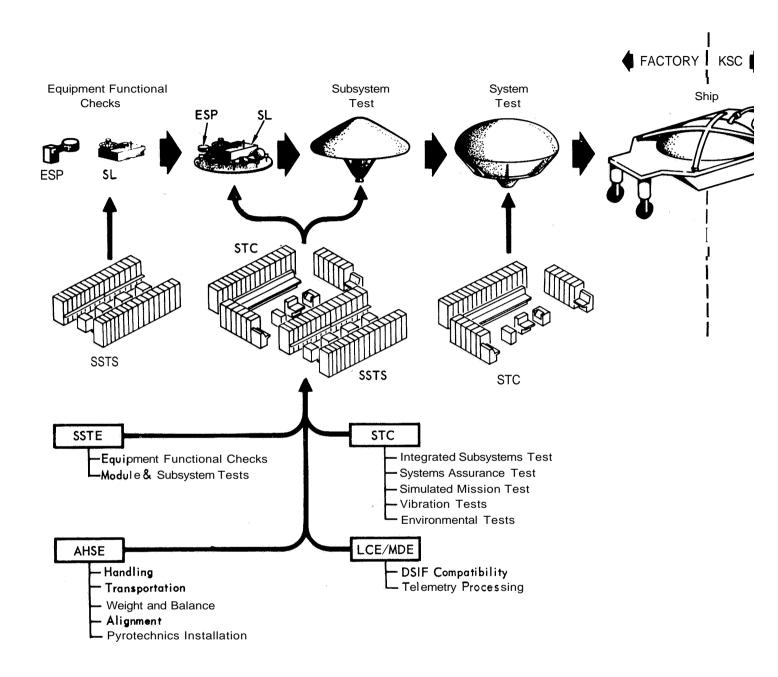
Assembly, Handling, Shipping and Servicing Equipment (AHSE) - Used for transportation and handling of the capsule bus and for weight and balance, alignment and rigging of structure and mechanical subsystems. Includes propellant and gas servicing equipment used at KSC.

3.1.2 <u>Test Utilization</u> — An overview of the use of OSE for the major CB test phases from factory through landed Mass operations is illustrated in Figure 3.1-1. The major test arrangements at the factory, KSC industrial area, and the launch pad are depicted in Figures 3.1-2, 3.1-3, and 3.1-4 respectively. A detailed description of the integrated Test Plan, Flight Acceptance Test Plan, and Mission Support Plan is provided in Volume 6.

3.2 DESIGN CONCEPT

- 3.2.1 <u>System Test Complex (STC)</u> The Capsule Bus System Test Complex (STC) equipment consists of approximately 40 cabinets of system level test equipment. Addition of the STC equipment for SLS and ESP is expected to bring this total to 84 STC cabinets. The major elements of the CB STC include:
 - o <u>STC Subsystem Consoles</u> Six sitdown consoles, each with a CRT for data display, a keyboard for addressing the Computer Data System (CDS), and critical hardline displays and commands.
 - o <u>Computer Data System (CDS)</u> A high speed, general purpose computer with multiple memory blocks and expandable 1/0 capability which centrally controls the entire STC.
 - o <u>CDS Peripheral and Interface Equipment</u> Tape transports, line printers, and card readers used to record data and provide inputs to the computer.
 - o <u>Test Director's Console</u> A sitdown console used for executive control of CB subsystems testing in the STC. This console enables the other consoles for single or combined subsystems testing, and contains a CRT display plus critical parameter displays.

OSE UTILIZATIONCAPSULE SYSTEMS INTEGRATION



LEGEND

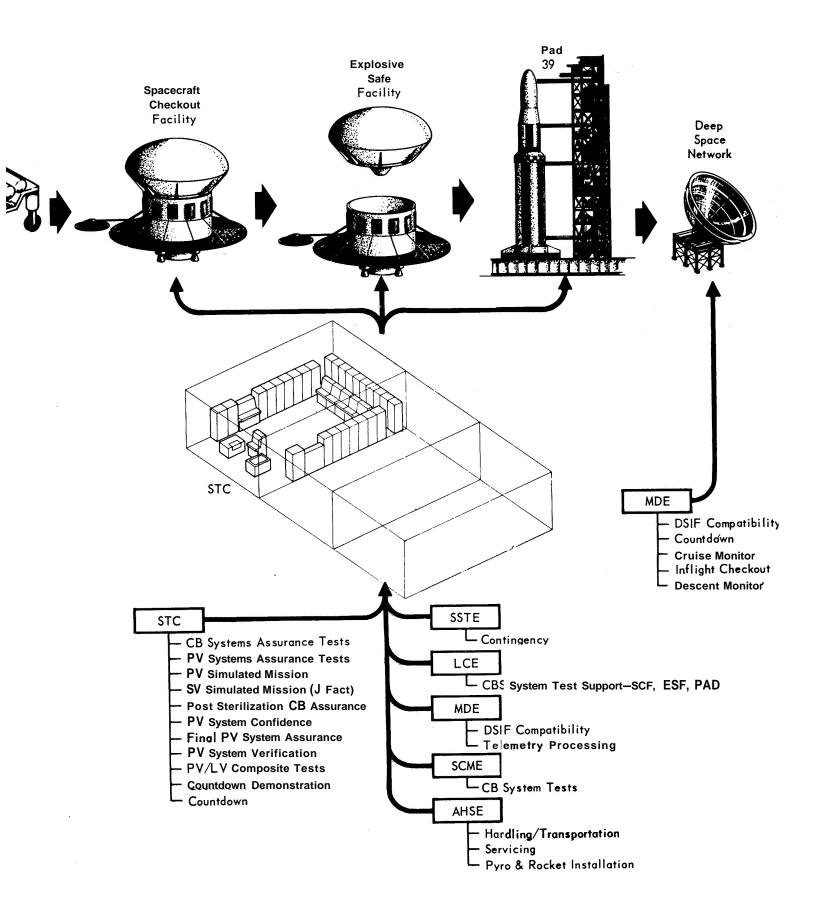
SSTE - Subsystem Test Equipment

STC - System Test Complex Equipment

LCE - Launch Complex Equipment

SSTS - Subsystem Test Sets

Figure 3.1**–**1

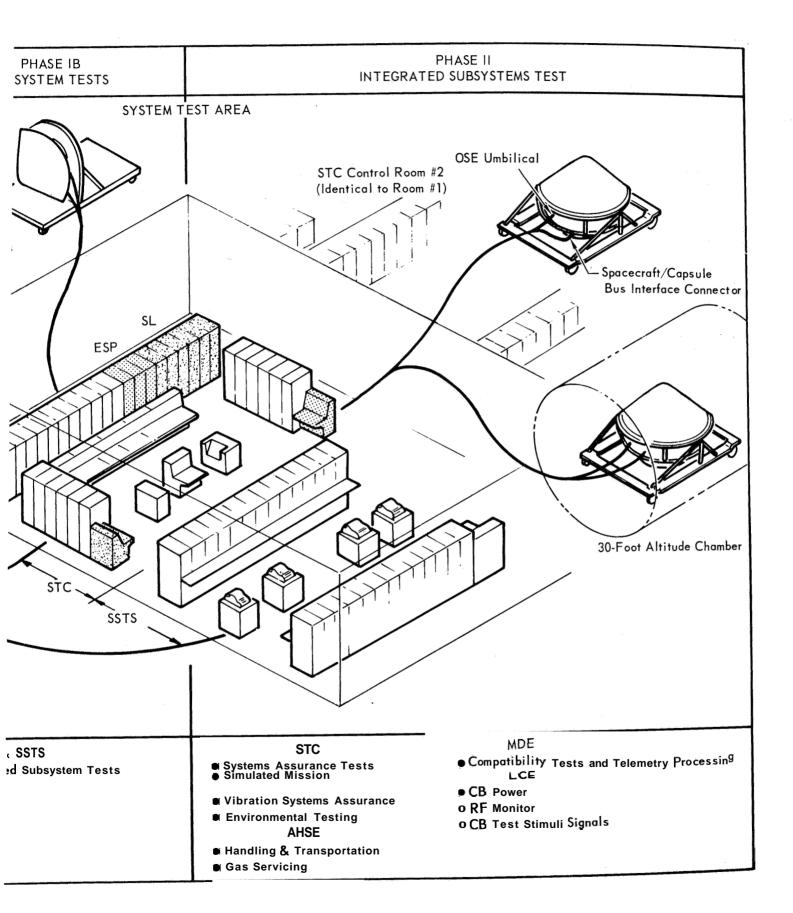


FACTORY TEST FLOW AND OSE UTILIZATION

	TACTORT TEST TEST 7	*************************************	1
TEST PHASE	EQUIPMENT FUNCTIONAL CHECKS (EFC)	PHASE IA MODULE TESTS	
USING AREA	Modules Aeroshell Lander Canister Adapter SLS ESP	CLASS 100,000 CLEAN ROOM SUBSYSTEM TEST AREA SL Lander SL SSTS	Capsule STC Con Room #1
OSE UT IL IZATION	SSTS Module Performance Verification Calibration and Adjustments Failure Analysis	SSTS Subsystem Tests Interface Simulation & Verification AHSE Handling Weight & Balance Installation	STC ● Integro

Figure 3.1-2

3-4-1



UTILIZATION OF OPERATIONAL SUPPORT EQUIPMENT AT KENNEDY SPACE CENTER

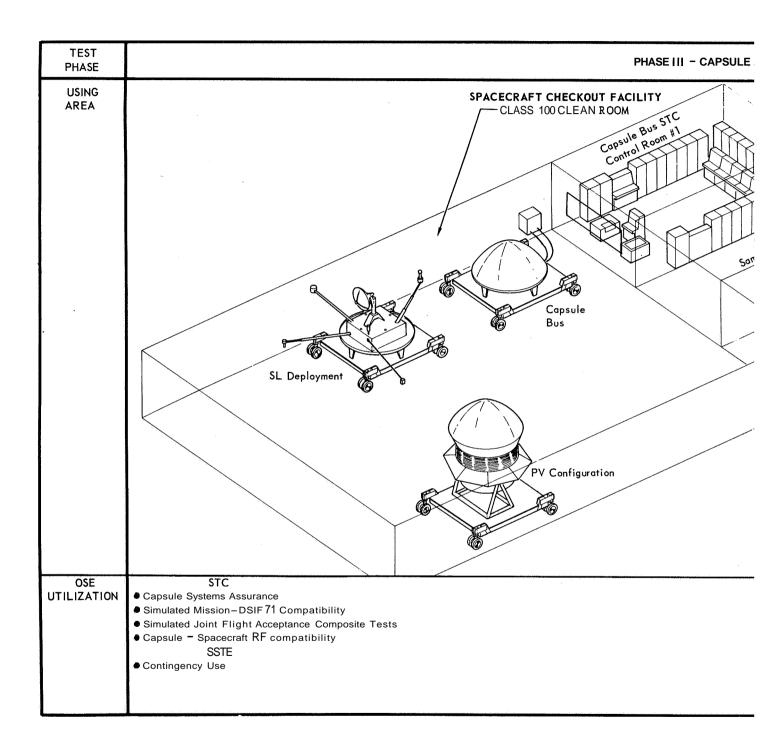
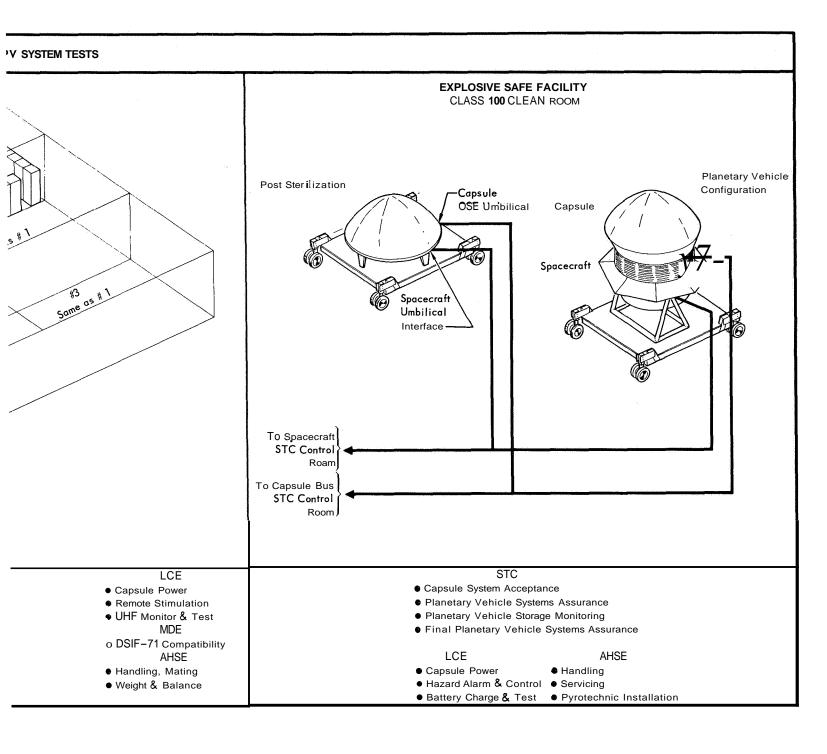


Figure 3.1–3



UTILIZATION OF OPERATIONAL SUPPORT EQUIPMENT KENNEDY SPACE CENTER AND DEEP SPACE NETWORK

TEST PHASE	PHASE IV LAUNCH CONTROL & MONITOR	MISSION
Using Area	Mobile Launcher Launch Control Center LCE Capsule Bus System Test Complex Control Room	Orbiting VOYAGER Spacecraft VOYAGER Planetary Vehicle MDE SFOF MDE
OSE Utilization	STC o CB Systems Verification o Joint Flight Acceptance Composite Tests o Countdown Demonstration o Launch Countdown LCE o Launch Conditioning o Power and Hazard Safing o Launch Control and monitor MDE o CB Compatibility with DSIF-71 o Decomm CB TM in System Test Complex	MDE o Display CB Analysis Data at SFOF o Decom CB TM Data in DSIF • Preprocess CB TM Data o CB Command Verification

- o <u>STC Required Mission Dependent Equipment (MDE)</u> An exact duplicate of the MDE equipment and software used at the DSIF stations to detect and decode the CB downlink data, and to generate the uplink commands that are required during the mission.
- o <u>STC Required Mission Independent Equipment (MIE)</u> An exact duplicate of the Telemetry and Command Processor (TCP) computer, used at the DSIF's.
- o Ground Data Transmission System (GDTS) A digital transmission system used' for transmission of TCM parameters and ground test data and commands between the STC and the Capsule Bus at remote locations.
- Simulators Spacecraft, ESP, SLS, and DSIF interface simulation and control equipment required for system level testing and compatibility demonstration.
- O Special Purpose STC Equipment -Timing and distribution, closed circuit TV (GCTV) intercomm, complex cabling, and other specialized equipment required to complete the STC equipment.

In operation, subsystem test engineers at the System Test Consoles select automatic test sequences or manual operations on the CRT keyboard. Response data is displayed on a Cathode Ray Tube (CRT) which can display up to 32 lines of parameters or computer outputted information in engineering units or English language. The CRT is also capable of plotting graphical data. An out-of-limits condition is indicated by a blinking of the affected parameters displayed on the CRT, plus a CRT display of the results of the OSE self-check. For critical parameters, an audio-visual alarm is also activated. As enabled by the test conductor, test operations may be conducted simultaneously on one or more subsystems. The high speed line printer at the Test Conductor's Console provides a permanent record of all test data required for flight acceptance.

The general arrangement of the STC and SSTS at the Capsule Bus Contractor's factory is illustrated in Figure 3.2-1. For combined system testing, the STC is supplemented by about 30 cabinets of Subsystem Test Sets (SSTS) for the Capsule Bus, plus an estimated 20 cabinets of SSTS for the SLS and ESP. The dual control room depicted provides a central location for control of subsystem and system testing during combined operations. After completion of Capsule Bus testing at the CB factory, the two sets of STC are transported to KSC and installed in the Capsule Contractor's control room, in addition to one STC previously transported to KSC with the Proof Test Model. Figure 3.2-2 depicts the arrangement of the CB Contractors control room at KSC. Figures 3.2-1 and 3.2-2 also illustrate the solution to the following

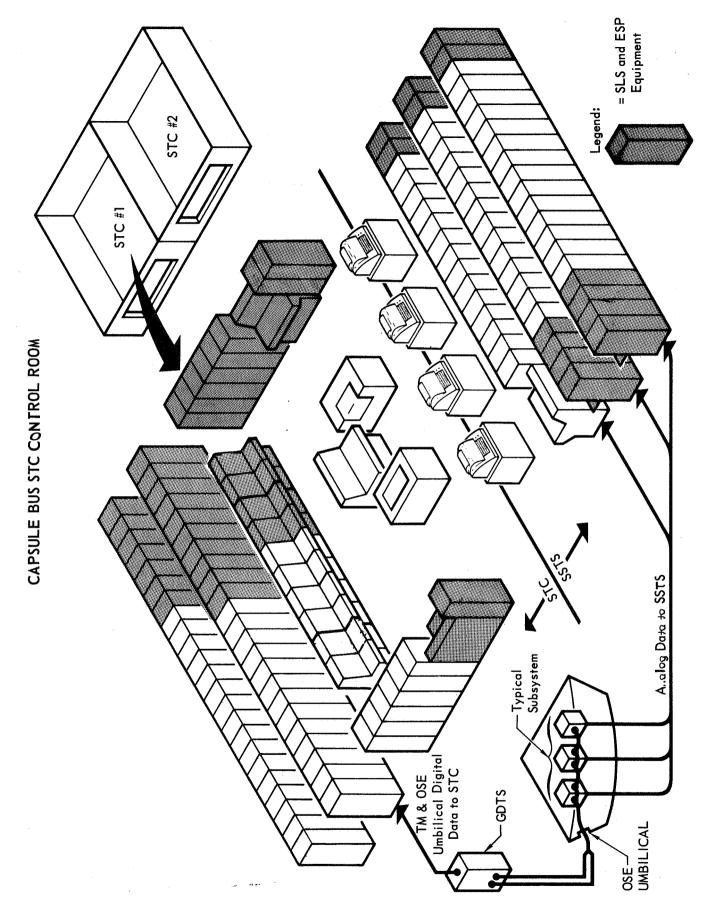


Figure 3.2-1

3-8

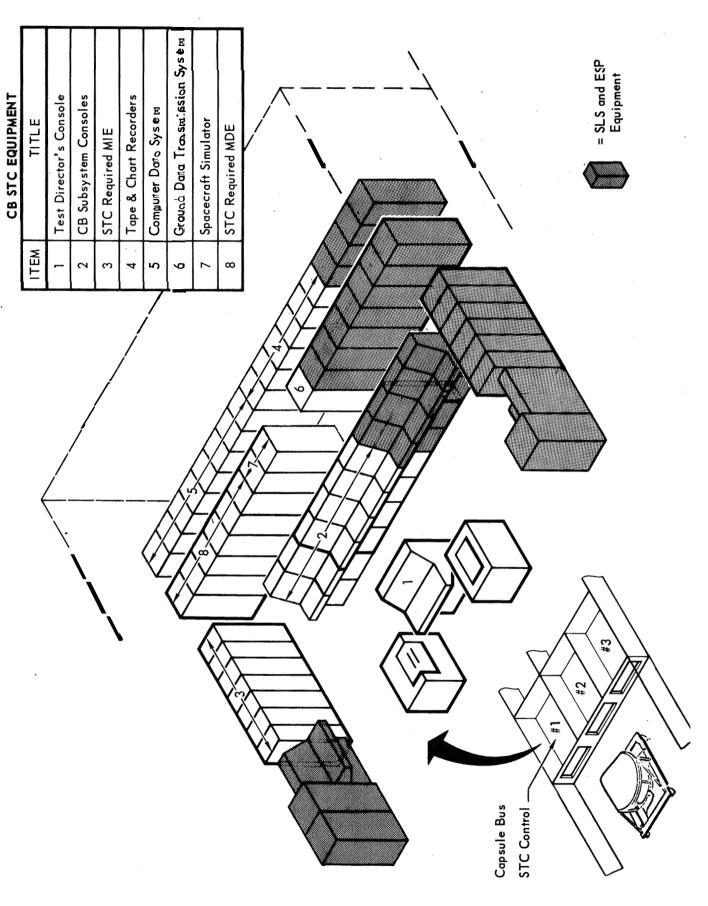


Figure 3.2–2

3-9

Capsule Bus problems:

- a. Data Transmission Through the Sterile Barrier The STC is designed to conduct integrated system level testing without the SSTS, using only the flight telemetry data, the in-flight checkout and monitor system, and selected critical parameters which are brought through the sterile barrier via the Spacecraft Umbilical and the OSE Umbilical. In our approach the SSTS test connectors used for subsystem test prior to canister installation do not duplicate the flight telemetry umbilical data, which is the primary source of test data used by the subsystem test consoles in the STC. This concept provides a clean functional and physical interface between the Subsystem Test Consoles and the SSTS.
- b. <u>Integrated Control Room Operations</u> The functional separation of the Subsystem Test Consoles from the Subsystem Test Sets (SSTS), coupled with elimination of the scheduled use of SSTS at KSC, greatly reduces the total quantity of equipment and floor space required, and reduces congestion in the control room. These are significant factors in integrated operations and facility requirements at KSC.
- c. STC Mobility The functional independence provided by the separate SSTS and STC concept reduces the total quantity of equipment to transport to KSC and thereby improves the capability for rapid transport and setup of the STC at KSC.

STC automation is based on the use of a high speed, general purpose computer to perform automatic test sequencing, parameter limit evaluation, alarm monitoring, data suppression, and OSE self-check. The computer also is used to time—tag data and to drive a high speed line printer and teletypewriter. The STC provides manual backup capability for fault isolation, program debugging, and program changes. The STC automation concept was selected as being more consistent with the Capsule Bus OSE constraints than the several alternative systems considered, which included a modified Mariner approach, Apollo Acceptance Checkout Equipment (ACE), and Saturn IV B Automatic Checkout System (ACS). As a candidate for the CDS computer in the STC, we have selected the Scientific Data Systems' Sigma 5 computer, which meets all automation requirements and provides maximum potential for program growth and future missions.

In addition to the STC computer data system used for test automation, the STC contains an identical duplicate of the Mission Independent Equipment (MIE) TCP computer and Mission Dependent Equipment (MDE) which is used in the DSN. The MDE and

MIE are used during checkout of the Capsule Bus, SLS, and ESP radio telemetry and command system and DSIF compatibility tests. Use of the same model computer for the CDS and MIE functions offers potential for time sharing, software commonality, and reduced hardware quantity. Computer selection will be dependent on the type of mission independent computers used in the DSN for the VOYAGER program. The SDS 920 computers currently in use in the DSN will require supplementary computers to process the MFSK telemetry proposed for the SLS, and to accommodate the total load associated with simultaneous support of dual Capsule Lander/SLS operation.

- 3.2.2 <u>Launch Complex Equipment (LCE)</u> Launch Complex Equipment (LCE) provides the capability to condition the Capsule Bus for Launch, to control and monitor critical functions on the launch pad, to fault isolate to the OSE or CB level, and to conduct system assurance and prelaunch checkout on the launch pad. LCE is used at the launch pad, the Explosive Safe Facility (ESF), and the Launch Control Center (LCC). The LCE uses selected STC equipment to minimize duplication. LCE consists of the following equipment:
 - o Ground Power and Distribution Equipment A two-way cabinet which provides automatic switching to facility backup power, and emergency backup power in case of total facility power failure, and dc power to the CB. This equipment is located in the base of the Mobile Launcher (ML) and at the ESF.
 - o <u>Remote Simulation Equipment</u> Two cabinets of test signal generation equipment, located on the Mobile Launcher (ML), and used to provide stimuli for on-pad testing of the CB.
 - o <u>UHF Receiving System</u> Contains a UHF receiving system mounted on the ML which demodulates the CB UHF transmitter output (brought out the Spacecraft flyaway umbilical from a parasitic antenna in the canister) and transmits the TM data to the STC via the Ground Data Transmission System. Spectrum and power-output measurements are made from two cabinets of equipment on the Mobile Launcher.
 - <u>CB Launch Monitor Console</u> A two way console located in the LCC, which has direct hardline access to the CB through the Spacecraft fly-away umbilical.
 CB, SLS and ESP subsystem status sent from the STC is also displayed on this console.
 - o <u>Hazard and Alarm Monitoring System</u> The system consists of two cabinets of equipment in the ESF, plus warning panels and controls in the CB Launch Monitor Console at the LCC and in the Propellant Subsystems Console in the

- STC. The system provides hardline monitoring of propellant and gas pressures, pyrotechnic arming circuits, and leak detection sensors, and is interlocked with the Complex 39 warning system and an explosion proof power source.
- o <u>LCE Required STC Equipment</u> Selected elements of the STC, including the CDS and MDE, required for on-pad testing of the CB. Test point access to the TCM is accomplished via the S/C flyaway umbilical.

Operation of the LCE is from the ESF and the STC during servicing, pyrotechnic checkout, de-orbit motor installation, and sterilization. Control shifts to the Launch Monitor Console in the LCC during launch pad operations. The STC Computer Data System provides automatic alarm monitoring, but approximately 20 critical parameters are hardlined to hardwired logic and displays to give maximum reliability for control of unsafe or potentially catastrophic conditions.

<u>Data Link Utilization</u> - The utilization and allocation of data links is a significant problem associated with VOYAGER Systems integration. The data link concept designed to clarify the complex relationship between the Spacecraft, Capsule Bus, and SLS, is summarized below.

A digital data link, the Ground Data Transmission System (GDTS), is employed between the CB and the STC during system level testing at the Spacecraft Checkout Facility, the ESF, and the launch pad. The GDIS uses the A2A and standard land line phone system plus CB multiplexing, coding and encoding terminals to provide low error data transmission and command verification. The link differs at the launch pad in that OSE umbilical test data is no longer available, and all the data used by the CB STC is routed through the Spacecraft fly-away umbilical to a junction box on the ML. At the junction box on the ML, CB data is split into three separate data trains.

- a. Data from the CB UHF and SLS Landed TM is transmitted by A2A landline to the Capsule Bus System Test Complex. An alternate RF data path for the SLS is also provided, using parasitic antennas to provide an RF link between the SLS and DSIF.
- b. The CB and SLS critical functions are analog hardlined to the CB/SLS LCE at the Launch Control Center.
- c. The SLS inflight checkout and cruise commutator output, interleaved with spacecraft data, is transmitted to the spacecraft contractor's ground station where the SLS data is stripped out and retransmitted to the SLS STC in the Capsule Bus control room.

Data Link utilization at KSC is illustrated in Figure 3.2-3.

- 3.2.3 <u>Mission Dependent Equipment (MDE)</u> The CB MDE consists of CB equipment and computer software required to support telemetry processing and provide data interface compatibility in the Deep Space Instrumentation Facility (DSIF) and the Space Flight Operations Facility (SFOF) at Pasadena. The major elements of MDE are summarized below and their interfaces with the DSIF and SFOF are illustrated in Figure 3.2-4.
 - o <u>Data De Multiplexing Equipment</u> Used at the Deep Space Instrumentation Facilities (DSIF's) to process the CB/ESP telemetry data from the S/C Mission Dependent Equipment to a level compatible with the capabilities of the existing DSIF Telemetry and Command Processor (TCP) computer.
 - o <u>CB Command Equipment</u> Used at the DSIF's to encode and verify commands sent from the TCP computer for transmission over the DSIF Spacecraft command link.
 - o Engineering Display Equipment Used at the DSIF's and the Space Flight
 Operations Facility (SFOF) for display of Capsule Bus TM data required for
 analysis of systems status and flight path.
 - o <u>Telemetry Command Processor (TCP) Software</u> Used to program the TCP computer for decommutation of the TM data from the TM pre-processor. This software also programs the computer for acceptance and verification of commands sent from the SFOF, and addresses the commands to the CB Command Equipment.
 - o <u>CB TCM Simulator</u> Used at the DSIF's to simulate the CB TM and Command System during pre-mission compatibility testing of the entire DSN with the CB TCM system.

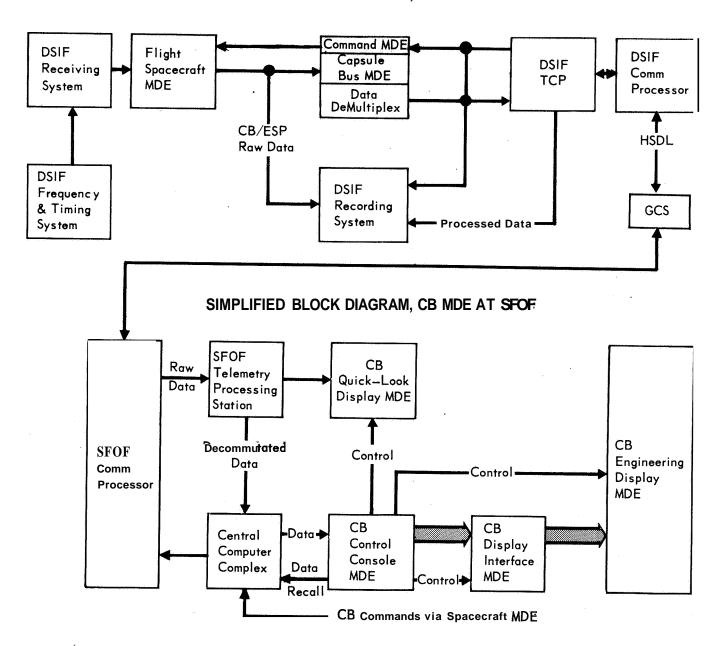
The MDE design approach is significantly influenced by the existing TCP computers (SDS 920) in the DSIF. The Data Demultiplexer reduces the load on these computers by demultiplexing and de-interleaving the real time and delayed time CB and ESP data.

3.2.4 <u>Subsystem-Level Test Equipment</u> - Capsule Bus subsystem level test equipment consists of approximately 30 cabinets of equipment which provide complete test capability for all subsystems composing the Capsule Bus System. Flight Subsystems functions are grouped to minimize duplication of OSE and to provide the maximum utilization of common designs. The same test set may be used for flight subsystem functional check, subsystems test during major module buildup and integration, subsystem tests in conjunction with the Systems Test Complex, and subsystem tests at

OSE DATA LINKS AT KENNEDY SPACE CENTER S/C Link - CB/SLS/ESP in-flight C/O & Cruise Commutator Data SLS RF to DSIF-71 Low Rate Transmitter Output High Rate Transmitter Output Command Receiver Input Junction Box DSIF-71 S/C Flyaway Umbilical RF to DSIF-71 (Same as Pad) CB & ESP Data **Explosive Safe Facility** to CB LCE PV SLS Inflight c/o & Cruise Commutator CB LCE Hazard output Alarm, SLS Landed Data Monitor & (Video) Low & High Rate Control .(A2A Lines) and Command Receiver Input CB TM Data and (\$/C Data Link) S/C CB LCE Monitor Data LCE LCE (A2A lines) LCE Monitor LCE Control & CB/SLS Mobile Functions and CB/SLS/EP Launcher Command Functions TM Data SLS Inflight C/O and Cruise Commutator via S/C Data Link LCE Control Functions and CB/SL Command Phonelines Functions CB/STC S/C Launch Monitor ŝtatus Control Console (LCE) Data Room Launch Control Center SLS inflight c/o CB CB and Cruise Control Commutator via Room \$/C Data Link **STC SCF**

Figure **3.2–3**

SIMPLIFIED BLOCK DIAGRAM, CB MDE AT DSIF



TCP = Telemetry Command Processor

HSDL = High Speed Data Link

GCS = Ground Communication System

KSC in the event of a contingency. The CB subsystem test sets and the flight equipment they support are listed below:

Subsystem Test Set (SSTS)

Guidance and Control

Electrical Power

Electrical Power

Electrical Power

Propulsion Reaction Control, Terminal Propulsion

Pyrotechnic Pyrotechnic

Radar Landing Radar, Radar Altimeter

Sequencer Sequencer

Telecommunications Antenna, Command, Data Storage,

Radio, Telemetry

Thermal Control Thermal Control

The SSTS used for equipment functional check at the CB contractor's facility is located in a Class 100 room to permit the use of short, analog hardlines for connecting the flight subsystem to the test set. An additional set of SSTS is located in the control room for use during major module buildup as shown in Figure 3.2-5. A total of 20 additional cabinets of SSTS is estimated for the SLS and ESP subsystem test sets.

To minimize human error and retain the inherent accuracy of the analog data, extensive use is made of digital displays in the SSTS. The Subsystem Test Sets provide stimuli, display, recording, time, loads, and alarm monitoring for the subsystem under test. Marginal performance testing is accomplished by programmed variation of the stimuli. Significant analogs or events are recorded on oscillographic recorders integral to the test sets.

The SSTS automation concept was established after evaluation of manual operation, selective automation, and automation of all SSTS. Test sequencing, control, and monitoring are automated for Guidance and Control, Radar, Sequencer and Telecommunications Subsystems Test Sets on the basis of cost effectiveness and the subsystem's compatibility with high-speed, repeatable test programming. The repeatability and continuity which automation imparts to the CB test history is a significant contribution to mission success. Incorporation of an independent automatic processor in each of these test sets provides minimum flight subsystem operating time, maximum scheduling flexibility, independent operation, and potential for future operation in a "satellite" mode under central computer control.

3.2.5 <u>Assembly, Handling Shipping, and Servicing Equipment (AHSE)</u> - Capsule Bus AHSE consists of the equipment required to assemble, service, checkout, weigh,

SSTS INSTALLATION AT CAPSULE BUS INTEGRATION SITE

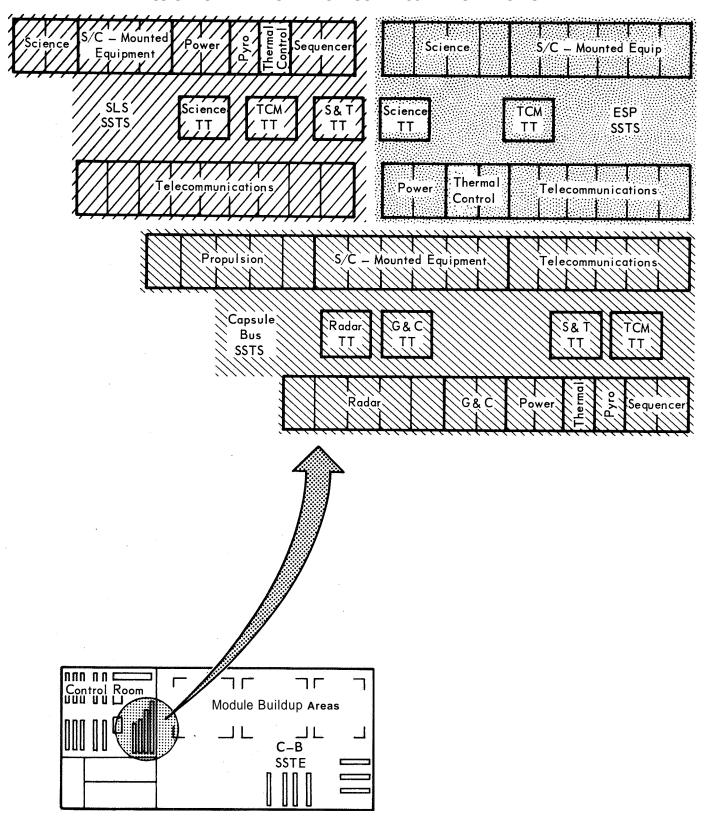


Figure 3.2–5

balance, align and ship the Capsule Bus System and components from factory through capsule/spacecraft integration. Approximately 25 items of AHSE have been defined, including the following major items:

- o Flight Capsule Transporter
- o Capsule Bus Handling Fixture
- o Capsule Bus Handling Dolly
- o Capsule/Canister Assembly and Checkout Stand
- o De-orbit Motor Installation Fixture
- o Forward Canister Work Stand
- o Propellant Loading Units
- o Flush and Purge Units
- o Capsule Bus Work Stand
- o Capsule Bus Weight and Balance Adapter
- o Lander Installation Fixture
- o Propellant Disposal System
- o Gas Servicing Unit

The design concept for AHSE is influenced primarily by transportation, safety, and sterilization constraints, in conjunction with the grouping of handling operations, to meet schedule requirements with the minimum equipment quantity. The physical size (approximately 20 ft diameter x 12 ft high) of the canistered capsule severely limits transportation methods. The B-377SG "Super Guppy" can encompass the canistered capsule and has been selected as the primary transportation mode. Because only one such aircraft exists, a backup mode (barge transportation) is selected as a feasible alternative. Helicopter lift from the factory to the barge avoids conflict with traffic ordinances and local loading facility constraints.

Major AHSE safety characteristics are summarized below and described in detail in Section 6.

- o Equipment utilized for handling pyrotechnics, propellants, etc., will be statically grounded and fabricated of non-spark producing materials.
- o Personnel protection will be provided by guard rails for upper platforms of work stands, covers for gear and cam assemblies and similar devices, and elimination of sharp or pointed projections.
- O Lockable casters and provisions for securing large fixtures and work stands to the floor and positive locking devices for all load sustaining, movable components will be provided.

The Flight Capsule Transporter is designed for either aircraft or barge transport and consists of a structural container plus running gear. The container suspension has four hydro-pneumatic struts at the corners of the base, and provides shock and vibration protection to the canister. Mobility is afforded by full-castered wheels which are part of the suspension strut assembly. The container has integral structure for hoisting, handling, and support.' To prevent contamination, a gaseous nitrogen supply system keeps the Flight Capsule in a nitrogen atmosphere with a positive pressure between the container and ambient of 1.0 to 2.0 psig. Servicing connections and redundant relief valves are provided in the container base plus a GN₂ supply for container replenishment and strut servicing.

The Capsule Bus Handling Fixture design is an example of grouping several functions within a single fixture. The fixture will support either the Aeroshell or Capsule, and mate with the Lander, De-Orbit Motor, or Parachute installation fixtures, and is wheeled to provide intrafacility mobility.

The Propellant Loading Units are mobile, self-contained storage and transfer units designed for use at the ESF prior to sterilization. A GN_2 pressure transfer system is employed to load the propellants in approximately fifteen minutes, with an accuracy of \pm 1% by weight, of the flight system's tank capacity. The Propellant Loading Units are manually operated, and contain direct pressure and quantity displays. Separate units provide MMH and N_2O_4 for the Terminal Propulsion Subsystem, and N_2H_4 for the Reaction control subsystem. Materials and design are similar to those used for Gemini hypergolic servicing equipment.

The Propellant Flush and Purge Units are mobile, self contained, and manually operated. Freon MF and isopropanol are employed as a flushing and decontamination agent, using GN₂ pressure transfer. An integral sump tank is provided for containing contaminated flush fluid.

<u>A Disposal System</u> at the ESF allows for venting of gases and disposal fluids during normal operation. A propane burner system prevents the venting of toxic gases or fluids to the atmosphere. If required at the launch pad, the Disposal System will provide the capability for emergency dump of propellants and an N_2 purge of explosive vapors which may be trapped within the canister.

<u>Leak Detection</u> at factory and the ESF before servicing is accomplished with a helium mass spectrometer (sniffer), using hand held probes and helium pressurized systems. After servicing, detection of toxic or explosive propellant vapors is accomplished by vapor detectors which are interlocked with the Hazard Warning Alarm System (LCE). The helium sniffers are also used in conjunction with the Canister Pressurization

Unit (CPU) to detect canister leakage. The CPU and its nitrogen gas supply are connected to the canister during sterilization to provide sterile gas make-up during heating and cooling cycles.

3.2.6 <u>Spacecraft Mounted Capsule Bus Support Equipment OSE (SCME)</u> - The SCME consists of approximately six electronic equipment cabinets of test equipment which provide the capability to test the capsule bus'elements and subsystems which are physically located in the spacecraft. The subsystems supported are:

Support Radio

Support Data Storage

Flight Capsule Command Decoder

Support Telemetry Equipment

This test equipment is identified as the CB/SC Mounted TCM Subsystem Test Set (SSTS) and is used for subsystem and system-level tests. During subsystem tests, this SSTS operates independently; when used in systems tests, the SSTS interfaces with the Telemetry and Command Processor (TCP) for telemetry data processing and with the Computer Data System (CDS) for test control. The test set may also be used at the spacecraft contractor's facility during integrated systems tests.

A canister and adapter simulator provides sensor input data during test and a telemetry simulator provides an FSK modulation signal for driving two UHF test transmitters. Simulated inputs to the Flight Capsule Command Decoder are provided by a command generator contained in the test set.

3.3 OSE EQUIPMENT SUMMARY - A summary of the most significant CB OSE hardware and using sites is illustrated in Figure 3.3-1. A detailed summary of OSE hardware requirements and using areas is contained in Section 9.

OSE EQUIPMENT SUMMARY

OSE	FACTORY	KSC	DSN
SSTE	∕Capsule Bus Subsystem Tes t Sets	Capsule Bus Subsystem Tes t Sets	
STC	Test Director's Console Capsule Subsystem Consoles Timing, Intercom and CCTV TCM Equipment TCP Computer (CDS Computer Ground Data Transmission System Simulators Computer Software	Test Director's Console Capsule Subsystem Consoles Timing, Intercom and CCTV TCM Equipment TCP Computer CDS Computer Ground Data Transmission System Computer Software	
LCE SESSION CONTROL OF THE PARTY OF THE PART	Power Control and Distribution Stimuli and RF Monitor Equipment	Power Control and Distribution. Stimuli and RF Monitor Equipment Launch Monitor Console	
MDE SON	TM Pre-processor Equipment Command Verification Equipment Computer Software	TM Pre-Processor Equipment Command Verification Equipment Computer Software	Computer Software TCM Pre-processor Equipment Command Verification Equipment SFOF Display Console CBS TCM/Simulator
AHSE	Capsule Bus Fixtures and Dollies Flight Capsule Transporter Lander Fixtures SLS Fixtures Servicing Units Flush and Purge Units	Capsule Bus Fixtures and Dollies Canister Stands and Dollies Lander Fixtures SLS Fixtures Servicing Units Flush and Purge Units Disposal Units	
SCME	CB Relay Link Test Equipment	CB Relay Link Test Equipment	

SSTE Used for STC During ategrated Test

Figure 3.3–1

SECTION 4

SYSTEM LEVEL SUPPORT EQUIPMENT

- 4.1 SLMMARY System level tests start at integration of the CB flight subsystems, SLS, and ESP modules, and end at Launch Vehicle (LV) lift-off. System Level Support Equipment required for these tests is used at the CB contractor's factory and KSC; and the configuration of these equipments is determined largely by the tests required at these locations, the accessibility of CB test points, and system level simulation required. Portions of these equipments are used in the Deep Space Network (DSN), and continue in use through mission completion. They control the CB and interpret data before and after landing on Mars. Hence, System Level Support Equipment is a vital factor in the success of the mission.
- 4.2 IDENTIFICATION AND USAGE OF SYSTEM SUPPORT EQUIPMENT These equipments are categorized according to support usage at the CB factory and KSC:
 - o <u>System Test Complex &TC</u>) used at St. Louis and KSC to exercise and determine the quality of the integrated CB subsystems, and identify faulty subsystems to the replaceable provisioned space level.
 - o <u>Launch Complex Equipment (LCE)</u> used for pad testing to demonstrate the readiness of the CB to perform the mission, identify faults to the support equipment or CB, and provide power and safety controls and alarms.
 - o <u>Missions Dependent Equipment (MDE)</u> CB peculiar equipment and associated software, used in the DSN to implement CB control and earth retrieval/interpretation of the CB data from lift-off to mission termination. MDE also is used in the STC and LCE to implement testing and to demonstrate CB/MDE compatibility prior to DSN usage.
- 4.2.1 <u>Interface Definitions</u> The STC, LCE, and MDE have two major requirements in common that significantly influence their system interfaces:
 - O CB Command Generation During flight, but before separation from the Spacecraft (S/C), the CB receives commands for in-flight checkout and cruise monitoring through the S/C command subsystem. The commands are verified however in the CB MDE at the DSIF's. These commands can also be used for ground systems testing at the launch-pad, at the Explosive Safe Facility (ESF), and in the SIC to partially satisfy the Launch Complex and System Test Complex test command requirements.
 - o CB TM Data Retrieval and Processing Before CB separation from the S/C and during descent to Mars, the CB transmits checkout and flight data to

the S/C TM subsystem. This data is eventually received in the S/C MDE and routed to the CB MDE for processing. This data link can also be used during system testing to partially satisfy the LCE and STC test requirements.

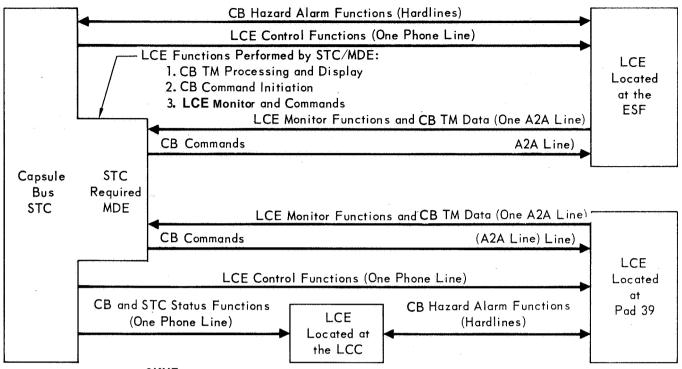
These common requirements can be satisfied by the sharing of the same equipment. Hence, Mission Dependent Equipment designed for DSIF usage is also used in the System Test Complex for command and TM data processing, and the SIC and MDE used at the CB contractor's and KSC are likewise used to accomplish Launch Complex Equipment (LCE) functions. This approach not only provides significant cost savings in designs and equipment quantities, but allows early compatibility demonstration of the MDE and LCE with the Capsule Bus. Figures 4.2-1 and 4.2-2 show how the MDE is used in the Systems Test Complex, and how the SIC required MDE is used in the LCE configuration.

4.3 SYSIEM TEST COMPLEX (STC) EQUIPMENT - The SIC is a computer controlled system level test complex capable of centralized automated or manual sequence control. It uses AN/CRT's for display of CB data and keyboards for gaining access to the computer for parameter changes or manual control. Telemetry and Command MDE is used in the SIC with an exact duplicate of the DSIF Telemetry and Command Processor (TCP) computer, and associated software for processing CB Commands and TM data. A Ground Data Transmission System (GDTS) is provided for transmission of ground test commands and data between the CB and STC. The SIC operation is under the executive control of the CB Test Director, who enables testing on selected groups of CB Subsystem. The central Computer Data System (CDS) controls the entire STC, evaluates the test data, conducts SIC self-test, provides test and emergency routines, and maintains a central log of all STC, facility, and CB data.

Our study of candidate computers for the CDS has led to the selection of a third generation computer. Rationale leading to this approach is;

- o Computers in this class have high speed operation and multiple 1/0 device expansion capability that allow growth and adaptability for larger, more sophisticated vehicles. This computer could control a CB, SLS, and ESP joint checkout facility if the customer chose to integrate the System Test Complex at the CB contractor's plant and at KSC.
- o Integrated circuits used in these computers provide increased reliability and reduced size.
- o The availability of these computers is expected to be better in the VOYAGER time period, and costs should be equal to or lower than second

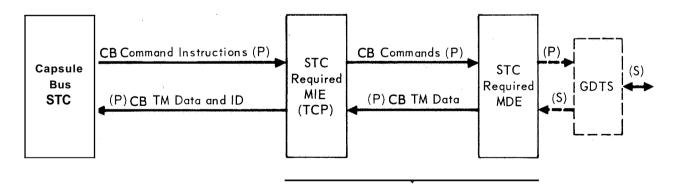
USE OF SYSTEM TEST COMPLEX EQUIPMENT FOR LCE FUNCTION KSC



Phone Line - Standard 3KHZ Telephone line A2A Line - Standard Wide Band Line

Figure 4.2-1

USE OF MISSION DEPENDENT EQUIPMENT AND MISSION INDEPENDENT EQUIPMENT IN THE SYSTEM TEST COMPLEX



All CB Normal Telemetry and Command Functions

(P) - Parallel Digital Data

(S) - Serial Digital Data

MDE = Mission Dependent Equipment

MIE = Mission Independent Equipment

Figure 4.2-2

generation equipment.

- o Many of these computers are tailored for telemetry and checkout use. Special hardwired logic is provided for high priority interrupts, on a weighted priority basis. Algorithms are available for a variety of TM and encoding formats, such as variable bit rate, variable word length PCM. Convolutional decoding algorithms and fast-Fourier transforms for MFSK processing are also available if required. We have chosen an SDS Sigma 5 series computer as an example for implementation of our approach.
- O We will provide software for the CDS in program modules. Support software for control of the CDS peripheral devices, and engineering units conversion programs required for manual computer control of the STC will be developed early in Phase D. Operational software for automatic test sequencing, data suppression, and limits comparison programs are required only for automatic computer control of the STC. Initial preparation of Support Software is planned to assure early availability of the STC for manual operations.
- 4.3.1 <u>Requirements and Constraints</u> The SIC meets both customer and CB contractor requirements and constraints. Those having major impact on SIC design are listed below:
 - o Acquiring, processing, distributing, and displaying of Capsule, OSE, and test facility data for real-time and non-real-time analysis by the use of a general purpose computer system.
 - o Providing capability to vary Capsule parameters, or externally supplied signals, for required performance testing.
 - o Isolating trouble to the provisioned spare replacement level.
 - o Centrally controlling or directing the Capsule or any of its subsystems, individually or in combination, through a complete or selected portion of a system test by the use of a general purpose computer system.
 - o Manually controlling the Capsule or any combination of its subsystems, to any operating mode, and in any sequence, provided for by the normal capsule test circuitry.
 - o Providing external power and simulating flight battery power. Providing battery power. Providing battery charge capability of the Capsule flight and test batteries.
 - o Provide growth capability to accept the anticipated test requirements of a CB for the 1975 launch opportunity.
 - o Providing safeguards to prevent the occurrence of damage to a Capsule or

any of the subsystems due to improper sequencing of test steps, or due to STC element malfunction or failure.

o Use of Selected Subsystem Test Equipment (SSTE) in the STC.

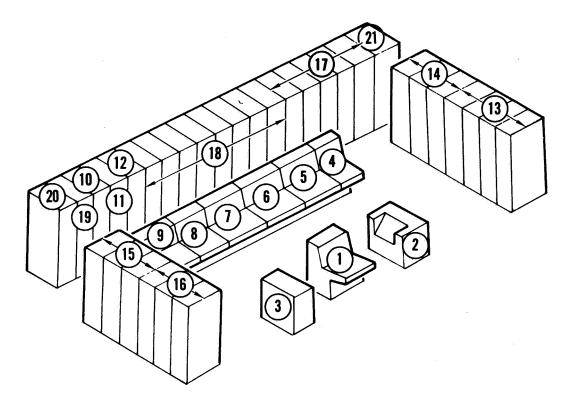
In addition, the CB sterilization requirements impose a test point inaccess-ability constraint unique to the VOYAGER program. We have provided the STC with access to the CB for test command and data points by maximum utilization of flight TM and the in-flight checkout system5 and the following access requirements:

- (1) S/C Flyaway Umbilical provide approximately twenty (20) wires and one coax cable for CB testing and monitoring. These will be available up to Space Vehicle lift-off.
- (2) <u>CB Canister Umbilical</u> provide approximately one hundred fifty (150) wires through the sealed canister for pyro and CB subsystem testing.

 These will be used for CB testing prior to installation of the PV shroud.
- 4.3.2 <u>Equipment Identification List</u> STC equipment can be divided into these functional groups;
 - o STC Consoles Six small consoles, each with a CRT for data display, a keyboard for addressing the CDS computer, and critical hardline displays and commands.
 - o Computer Data System (CDS) A third generation computer with multiple memory blocks and expandable 1/0 capability which centrally controls the entire STC.
 - o CDS Peripheral and Interface Equipment Tape machines, line printers, and card readers used to record data and provide inputs to the computer.
 - o STC Required MDE An exact duplicate of the MDE equipment used at the DSIF stations to detect and decode the CB down-link data, and generate the up-link commands that are required during the mission. Software for the Telemetry and Command Processes (TCP) computer is also in this category.
 - o STC Required MIE An exact duplicate of the Telemetry and Command Processor Computer used at the DSIF's.
 - o Ground Data Transmission System (GDTS) A two way, very low error probability system used to transmit CB TCM parameters and other non-TCM 'ground test data and commands between the STC and remotely located OSE.
 - o Test Director's Console This console is the focal point for executive control of CB subsystems testing in the STC. This console has complete critical hardline displays as well as a CRT, and enables the other con-

- soles for single or any combination of subsystems testing.
- o Simulators S/C, SLS, and DSIF interface simulators and control equipment required for testing and compatability demonstration.
- o Special Purpose STC Equipment Timing and distribution, CCTV, intercomm, recording, complex cabling, and other support equipment required to complete the STC complement.
- 4.3.3 Physical Characteristics Figure 4.3.-1 shows the proposed layout of the STC with the various equipment identified. This arrangement is the same for both CB contractor and KSC locations. It contains 32 cabinets, 7 consoles, 2 computer controlled printout devices.
- 4.3.4 Operational Description The STC, shown in the block diagram of Figure 4.3-2 has these salient operational features:
 - o Closed-loop computer controlled test sequence control (by test routine blocks) for automatic CB testing.
 - o Manual test sequence control by the use of key-board access to the computer from each subsystem console and the Test Director's Console.
 - o AN/CRT displays for maximum flexibility.
 - o Suppressed data printout using fixed point and floating point techniques.
 - o Automatic limits comparison of all data.
 - o Priority interrupt techniques for immediate execution of safety sequences for critical CB or emergency conditions.
 - o Use of MDE, and the Mission Independent Telemetry and Command Processor (TCP) Computer.
 - o Demodulation and decommutation of the CB to S/C UHF data link independent of the S/C S-band retransmission link.
- 4.3.5 <u>Interface Definition</u> The significant interface of the STC occurs with facilities at KSC, where considerable distances exist between the STC, and the CB at the ESF or pad. This interface occurs to a lesser extent at the CB contractor's facility where the CB is being tested in the altitude chamber. Figures 4.3-3 and 4.3-4 show how this interface is made using one standard phone line for transmission of commands to the CB and remote OSE, and one wide band A2A type line for transmission of CB and OSE data back to the STC.
- 4.3.6 Reliability and Safety Our approach to automation of the SIC by use of the CDS provides for real time, high speed testing of the CB, yet retains man-in-the-loop for critical contingency functions not foreseen in the computer programming. Application of this approach provides:

CAPSULE BUS SYSTEM TEST COMPLEX EQUIPMENT



ITEM	TITLE
1	Test Director's Console
2	High Speed Line Printer
3	X-Y Plotter
- 4	TCM Console
5	Sequencer and Pyrotechnics Console
6	Radar Console
7	Guidance and Control Console
8	Propulsion and Thermal Control Console
9	Power and Distribution Console
10	Timing Distribution and Data Conversion Unit
11	intercom, P.A. Access, Telephone
12	SLS and ESP Simulators
13	TCP Computer
14	TCP Peripheral Equipment
15	Magnetic Tape Recorders
16	Strip Chart Recorders
17	CDS Computer
18	CDS Computer Peripheral Equipment
19	Ground Data Transmission System
20	Spacecraft Simulator
21	CB MDE

CAPSULE BUS SYSTEM TEST COMPLEX (STC) BLOCK DIAGRAM

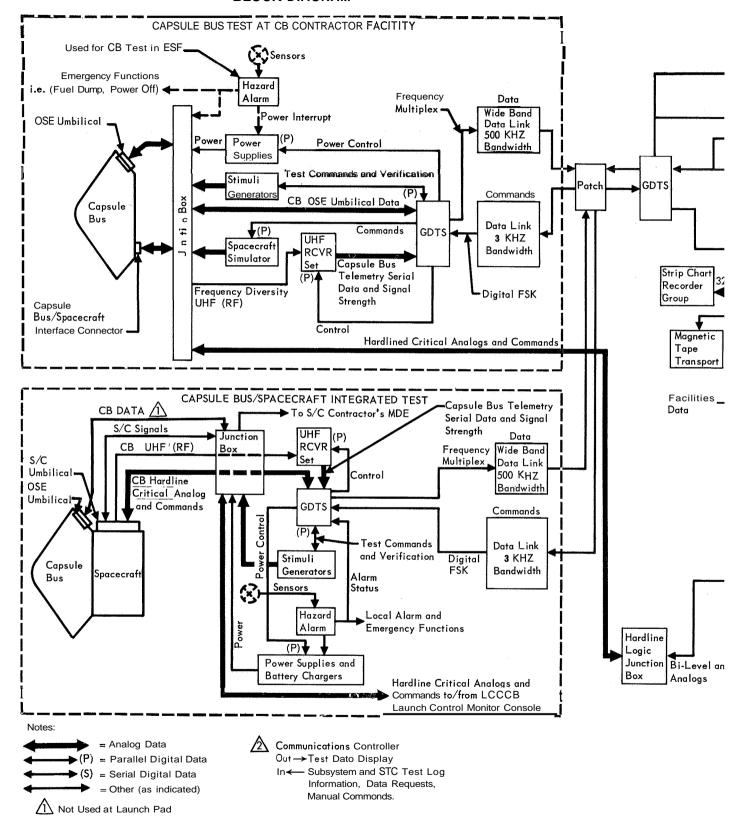
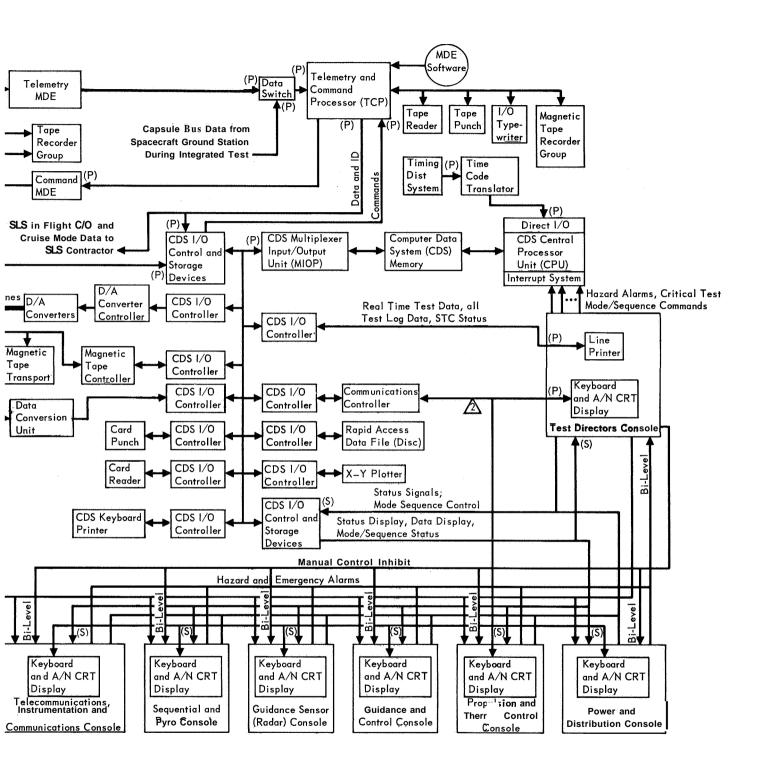
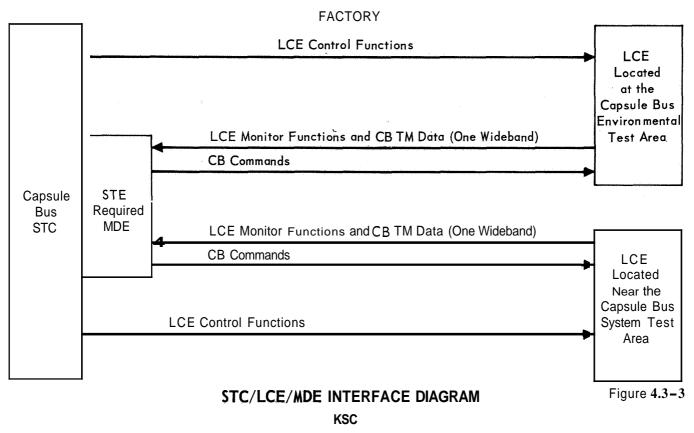
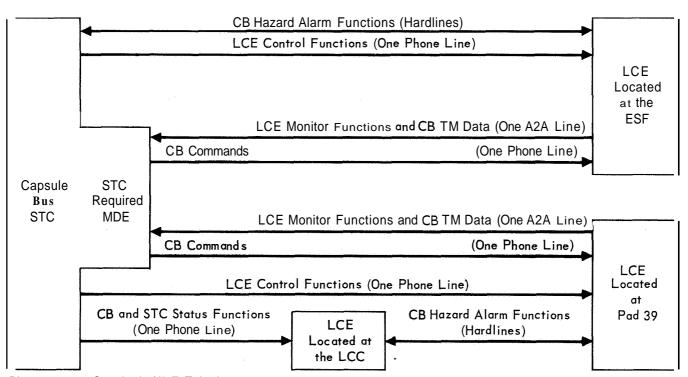


Figure 4.3-2



STCILCEIMDE INTERFACE DIAGRAM





Phone Line - Standard 3KHZ Telephone Line A2A Line - Standard Wide Band Line

Figure **4.3-4**

- o High test repeatability, with minimum operating time on CB equipment.
- o On-line STC self-test, with computer augmentation to assist in STC fault isolation.
- o High priority automatic emergency sequencing of the CB and STC to protect the CB and personnel.

The CDS computer chosen will be third generation, have built-in test capability, and use micro circuits for the active elements. These features provide high reliability to this important element of the STC. However, complete manual back-up capability for emergency sequencing and critical displays is provided to meet any anomaly.

Section 4.4 will show usage of STC to implement a large portion of the LCE requirements. Those STC elements used in the launch phase must meet the reliability requirements of Section 4.4.4.

- 4.3.7 <u>Development Status</u> Equipment used in the SIC will require minimum development. The significant development visualized is software for the CDS computer which controls the STC. We have minimized the risk in this area by separating the software program into two groups as described in Paragraph 4.3: the Support Software, used in both the manual and automatic SIC modes, and the Operational Software, used for automatic, closed loop operations. The Support Software required for early SIC operation uses programs which are largely developed and in use. A significant part of the executive routines are delivered with the computer. In this manner, delays in SIC operation due to software availability are minimized. A detailed description of software development is provided in Section 8.
- 4.3.8 <u>Growth Capability</u> Our STC approach provides significant growth capability to meet the test requirements of a more sophisticated mission at the 1975 launch opportunity specifically in these areas:
 - o CDS computer third generation computers posess increased speed and power which permits the future addition of 1/0 devices, thus providing capability to process much larger quantities of data than presently required.
 - o CRT Displays Provides maximum display and format capability on a page call up basis.
- 4.3.9 <u>Equipment Functional Description</u> The equipment groups identified above are functionally described in detail as follows:

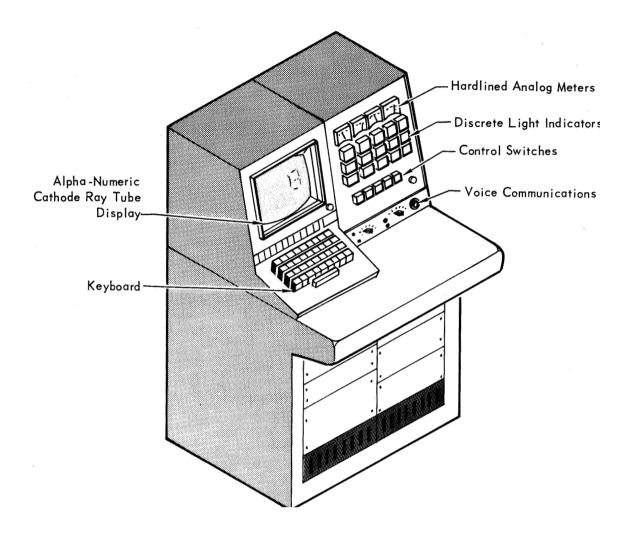
4.3.9.1 STC Consoles

a. Identification and Usage - The STC subsystem consoles are used in the

performance of integrated systems level tests of the Capsule Bus. Although each console is part of its own Subsystem Test Equipment (SSIE), the subsystem consoles are described in this section because of their extensive functional interface with the STC. The subsystem consoles include:

- o TCM Instrumentation
- o Power and Distribution
- o Sequencer and Pyrotechnics
- o Radar
- o Guidance and Control
- o Propulsion & Thermal Control
- b. <u>Design Characteristics</u> The subsystem consoles directly interface with the CDS computer in the STC. Each console can generate computer instructions to initiate tests of its Capsule Bus subsystem via a keyboard display assembly. The keyboard is also used to send Capsule Bus test data call up instructions to the computer which will in turn display the data in english language on a display cathode ray tube (CRT). The digital, computer oriented interface of these consoles makes possible a high degree of design commonality and a close similarity of physical characteristics, interfaces and operational capabilities.
- Physical Characteristics A typical console configuration shown in Figure 4.3-5 consists of a two-bay sitdown type console with slanted control and display panels containing an alphanumeric cathode ray tube (AN/CRT) capable of simultaneously displaying any 32 test parameters available from the CDS computer. Analog and discrete indicators and controls for critical functions are also provided. The writing surface contains a keyboard assembly for communication with the CDS computer. Section 4.3.9.2 discusses the keyboard display in detail. Located below the shelf is a console dc power supply, logic unit (input/output buffer for GDIS), ac power panel, blowers and storage drawer.
- d. <u>Operational Description</u> Each console's subsystem monitor and control functions are described below:
 - o <u>TCM Instrumentation Console</u> Provides the operator with the capability to monitor the Capsule Bus TCM subsystem when the STC is in the automatic or manual modes. The console keyboard is used to generate TCM subsystem data and MDE status requests that instruct the CDS computer to print, in engineering units, the requested data. Upon receipt of

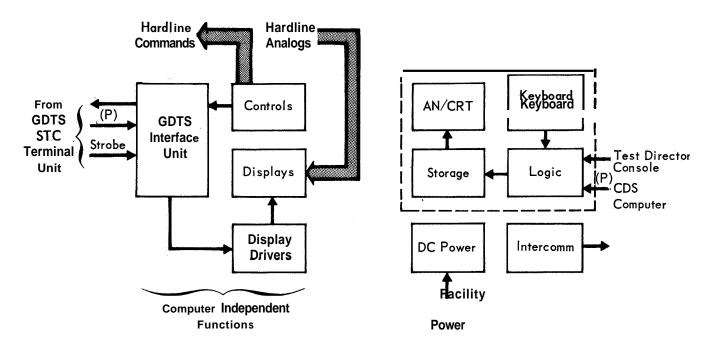
TYPICAL STC CONSOLE



- an enable signal from the Test Director's Console, the keyboard can generate TCM subsystem test requests, the results of which are automatically printed on the AN/CRT.
- Power and Distribution Console Provides the operator with the capability to monitor the Capsule Bus Power Subsystem and generate test requests in the same manner as described for the TCM Instrumentation Console. In addition, the console displays status information pertaining to the remote located Ground Power and Distribution Equipment and local SIC facility power via analog and bilevel discrete indicators. Critical functions are transmitted via the GDIS and redundant hardlines in addition to their normal CDS computer link, and have an alarm indicator associated with each. Control switches related to these critical functions provide supplemental manual control.
- o <u>Sequencer and Pyrotechnics Console</u> Provides the operator with the capability to monitor and test the Capsule Bus Sequencer Subsystem and pyrotechnic circuits via a keyboard display in the same manner as the other subsystem consoles. The console also provides display of Hazard Alarm and Monitor System functions related to the pyrotechnic subsystem by discrete indicators and provides manual backup controls by which the operator can sequence the Capsule to a safe condition.
- o <u>Radar Console</u> Provides the operator with the capability to monitor and test the landing radar and radar altimeter subsystem using a keyboard display assembly as described for the other subsystem consoles.
- o <u>Guidance and Control Console</u> Provides the operator with the capability to monitor and test the Capsule Bus Guidance and Control Subsystem by use of a keyboard display assembly in the same manner as described for the other STC subsystem consoles.
- o Propulsion and Thermal Console Provides the operator with the capability to monitor and test the Propulsion and Thermal Subsystems using a keyboard display assembly as previously described for the other STC subsystem consoles. In addition, this console displays and generates alarms for critical parameters related to the Hazard Alarm and Monitor System including propellant and gas pressures, temperatures and vapor detector status. Manual control and monitor functions required to return the Capsule to a safe condition are independently transmitted by hardlines as a backup to the normal CDS computer control.

- e. <u>Typical Console Interface</u> The functional block diagram of Figure 4.3-6 shows the interfaces common to the typical STC console including CDS computer, Test Director's Console, facility power, STC intercom, GDIS and analog hardlines.
- 4.3.9.2 <u>Computer Data System (CDS)</u> The CDS consists of a high speed third generation general purpose computer and peripherals which is used in the System Test Complex (STC) to satisfy the following requirements and constraints:
 - a. Control the capsule or any of its sub-systems through a complete or selected portion of a system test.
 - b. Control and/or direct the STC elements during system test sequences.
 - c. Acquire, process, evaluate, store and distribute all capsule and STC elements data required for real time and non-real time analysis of all capsule system tests performed by the STC.
 - d. In conjunction with STC elements, provide means to manually control the capsule test to any mode, in any mode, and in any sequence.
- 4.3.9.2.1 <u>Physical Characteristics</u> The CDS configuration is shown in Figure 4.3-7. It will consist of:
 - a. Central Processor Unit (CPU)
 - b. Core Memory
 - c. Multiplexer Input/Output Processor (MIOP)
 - d. Input/Output Device Controllers
 - e. CDS peripheral Group
- 4.3.9.2.2 <u>Functional Description</u> The functional description of the CDS is as follows: (See Figure 4.3-8 for functional block diagram).
 - a. <u>Data Acquisition</u> The CDS acquires data from the Telemetry and Command Processor and other STC elements. The data is stored in program controlled registers or core memory for subsequent limit checking, data suppression, and output to peripheral equipment for display, recording, mass storage or status monitoring. Typical data input to the CDS is as follows:
 - o Range timing signals from central time distribution group for time tagging data and sequencing test events.
 - o Capsule test data from the Ground Data Transmission System (GDTS) for monitor and evaluation
 - o Manual commands from SIC elements including the Test Director's Console

FUNCTIONAL BLOCK DIAGRAM TYPICAL STC CONSOLE



(P) Parallel Digital Data

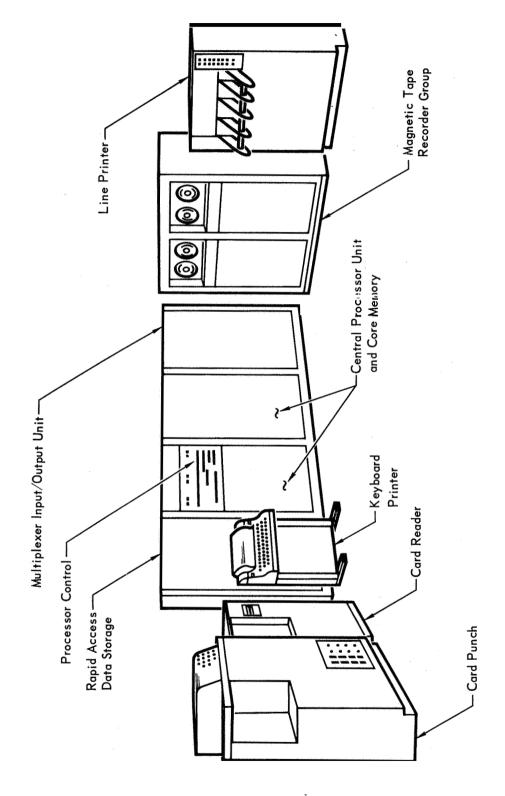


Figure 4.3-7

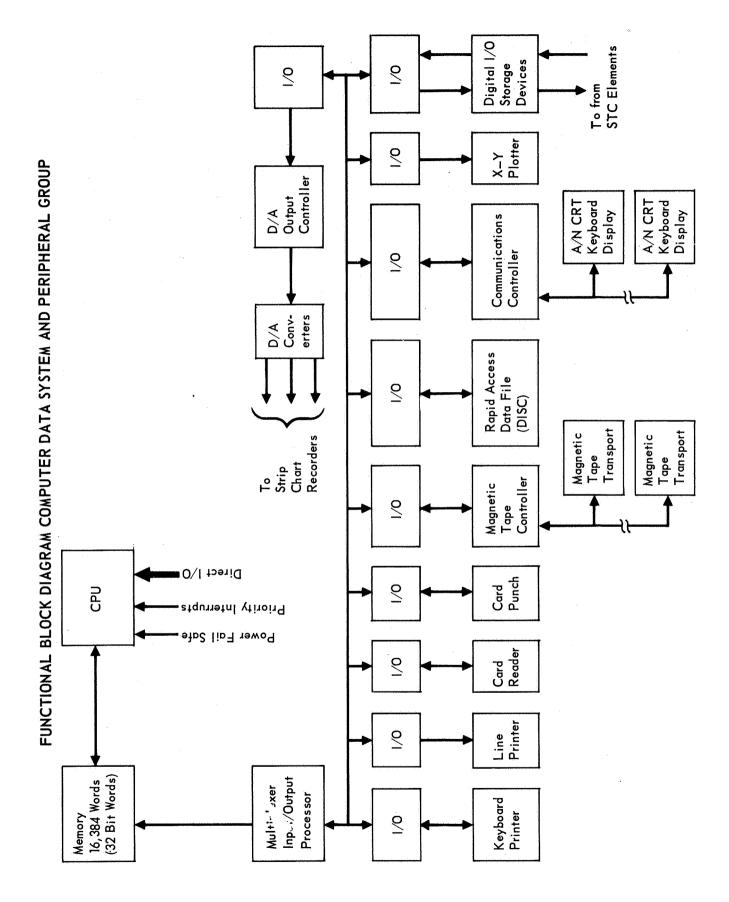


Figure 4.3-8 4-17

- o STC status signals and data requests from STC elements and the Test Director
- o Hazard alarms and emergency signals from STC elements
- o Facility power status and condition
- b. <u>Data Processing and Data Evaluation</u> The operations performed by the CDS fall into two major areas; real-time data processing and evaluation, and post-test data processing and evaluation.
 - o Real-time The data processing and evaluation normally accomplished by the CDS on a real time basis will be only that data which is required for successful completion o€test. Data is acqcired, converted into the required format, limit checked, suppressed, tagged with test limits code, and read into memory for output to CDS peripheral group and SIC elements. Status of sub-systems, and SIC elements is monitored continually, updated and stored in memory for output to peripheral devices, SIC elements, and the Test Director's Console. Critical temperatures, pressures, power supply voltages, etc., are monitored continually for hazardous conditions. When a hazardous condition or out of tolerance condition is detected, an appropriate priority interrupt is generated that initiates an STC self check followed by a corrective action or safe-operation sub-routine in the CDS. sub-routines either sequence the affected sub-system or STC element to a safe operating mode, or immediately remove power depending upon the criticality of the unsafe condition.
 - Post Test (non-real-time)— The data processing and evaluation accomplished by the CDS on a non-real-time basis will be that data which must be further evaluated for troubleshooting, signature analyses, trend analyses, data expansion, and playback of previous tests or portions of tests. These special test modes are controlled by the CDS on command of the Test Director and/or CDS operator. Repetitive test routines are initiated by manual entry of the test routine address by the CDS keyboard operator. The CDS verifies that the subsystems and STC elements are in a ready condition prior to initiating the test sequence. Unique test programs or detailed troubleshooting sequences are manually entered in the CDS by the keyboard operator.
- c. <u>Trend Analysis</u> Realizing the advantages of providing a trend analysis for system and sub-systems, McDonnell is presently studying methods of

implementing the inherent trend analysis capability of the CDS, to provide an accurate and rapid method of detecting important trends in the system and subsystems prior to and subsequent to launch. The major modes of trend analysis being considered are:

- On Line Analysis This mode is used simultaneously with the real time test program and provides a continuous monitor of system or subsystem trends. However, the amount of historical data required to be stored in core memory versus the normal real time testing program of the CDS limits the number of trends that can be monitored, evaluated and plotted. Once the real-time test program is sufficiently developed to provide an indication of the remaining computer bandwidth and core memory available, a reasonable estimate of a real-time trend analysis program can be made.
- o Off Line Analysis This mode can be run on a low priority on-line basis during real-time tests or can be run on a post test basis during post test data evaluation. Therefore, it is virtually open ended in that if desired, subsystem 'data taken from the first test ever run on the subsystem can be compared with all subsequent test data and evaluated for significant trends. The historical data can be stored in disc memory or on magnetic tape which allows an unlimited amount of data to be retained for future use.
- d. <u>Input/Output Transfer</u> The basic element of CDS information is a 32 bit word. The core memory, which is addressable by either the CPU or the MIOP will have a minimum of 16,384 32-bit words (expandable to 131,072).

The CDS operates in either the master mode or the slave mode. The master mode is the basic operating mode of the CDS. In this mode, the resident executive program controls and supports the operation of other programs (which may be in either master or slave mode). The slave mode is the problem solving mode of the CDS.

- e. <u>1/0 Operation</u> Input/Output operations are primarily under control of the MIOP. This allows the CPU to concentrate on program executors. Normally, the CPU will execute instructions, the MIOP executes commands, and the device controllers or 1/0 devices execute orders.
- 4.3.9.2.3 <u>CDS Peripheral Group</u> The CDS uses one MIOP but can accommodate up to 8 MIOP's each capable of supporting simultaneous operation of 32 Input/Output devices.

This provides the CDS with a future mission expansion capability of operating with up to 256 Input/Output devices connected. The .CDS peripherals include:

- a. <u>Magnetic Tape Recorder Group</u> Two 9-track, IBM compatible, high speed incremental magnetic tape recorders are provided that operate at 75 IPS to provide transfer rate of up to 480,000 bits per second. These recorders will be used to record:
 - o Test results as a BCD recording of the data printed on the high speed printer at the Test Directors Console.
 - o Test history, including command and control requests initiated by the Test Director and the STC Sub-system OSE Operators.
 - o Records of parameter changes entered either manually by STC keyboards or by the tab card reader.
 - o Trend analysis data, command inputs, and analog direct access data.
- b. <u>Multipurpose Keyboard Displays</u> Keyboard Displays will be provided at the Test Directors Console and selected STC subsystem consoles. These keyboard displays will provide the following capabilities:
 - o A means of manually entering parameter changes, altering or writing in new slave mode programs for selected subsystems, and call-up of specific data for display. This will allow the Test Director and/or Subsystem OSE Operator to manually control the Capsule or any of its subsystems to any operating mode, and in any operating mode to any sequence provided for by the CDS resident executive program.
 - o A means of editing text (parameter changes, slave mode program changes, data requests, etc.) prior to transmitting the message to the CDS. This is accomplished by the operator typing in his message (which is displayed on a selected area of the CRT), performing his edit function, and then transmitting the message when desired.
 - o Displaying, on an 8 1/2 x 11 inch alpha-numeric CRT, 32 lines (86 characters per line) of test data form the CDS either under program control or as requested by the operator. The operator will have the capability to roll data forward or backward, back space and write-over by character or line, and erase by character, line, or page as desired.
- c. <u>Line Printer</u> A fully buffered line printer will be provided for the Test Director that will be capable of printing at speeds of 600 lines/minute minimum with 132 print postions per line. The printer will record the results of the test, provide direct correlation with the test plan,

- indicate the nature of any malfunctions, and record any deviations from the pre-programmed plan. Upon successful completion of the test, the printer will prepare the test data record for buy-off. As a minimum, the printer will record the following:
- o Prior to, and subsequent to test, the printer will record test log information such as lists of equipment under test and accumulative operating times, identification of test being performed, and status, identification, and conditions of STC elements and test facilities.
- o During all tests the printer will record test data such as date and time in GMT, status changes and event occurrences, operating modes of the STC and Capsule, alarm messages, procedure in use and step number, and all other data (data display suppressed) necessary for real time evaluation of the Capsule or subsystem under test.
- d. Card Reader & Card Punch Equipment A standard 80 column card reader with reading speeds of up to 400 cards/minute and a card punch with punching speeds of up to 300 cards/minute will be provided. The card reader and punch will be used for assembling new programs and entering parameter changes during tests.
- e. Rapid Access Data Storage System (RAD) The RAD will provide an additional memory storage capacity for the CDS without disturbing CDS core memory or existing programs. This system will enable whole or partial test programs or sequences to be assembled, written into disc memory, and called up by the CPU when required.
- f. <u>Keyboard Printer</u> The keyboard printer will be used by the CDS operator to perform functions such as operations control, error and status message reporting, and similar forms of communications with the CDS. This provides direct, manual input to the computer, and automatic hard copy printout of computer output.
- g. X-Y Plotter A two axis digital incremental plotter will be provided for recordings of selected signals for real time and post test analysis.
- 4.3.9.2.4 <u>Interface Definition</u> The CDS will interface with the following components: (See Figure 4.3-9 for interface drawing).
 - a. STC subsystem and STC unique OSE (STC Elements)
 - b. Telemetry and Command Processor (TCP)
 - c. Ground Data Transmission System (GDTS)
 - d. Test Director's Console

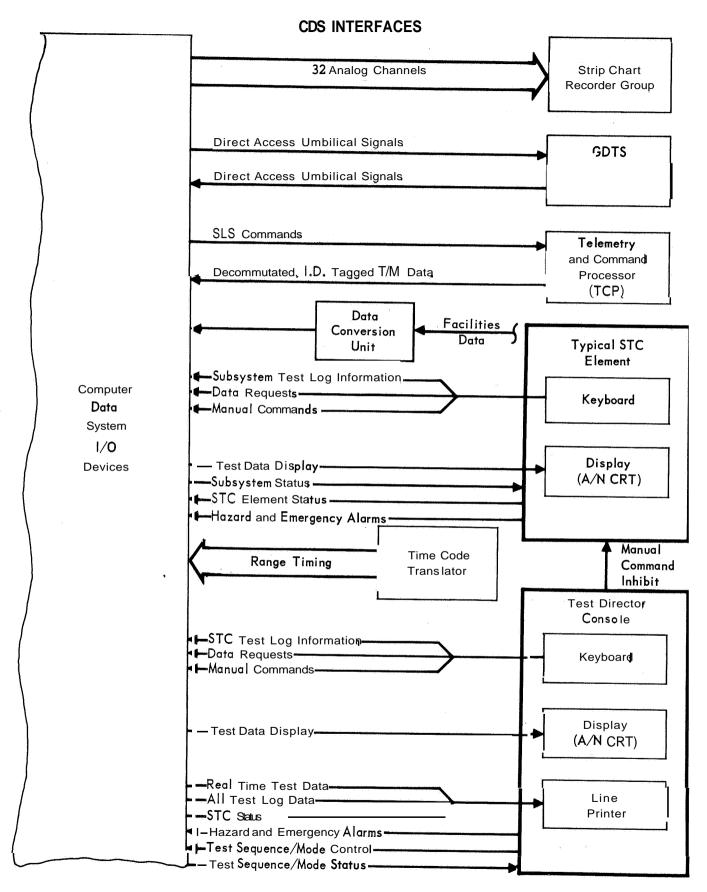


Figure 4.3-9

- e. Timing Distribution Group
- f. Data Conversion Unit
- g. Strip Chart Recorder Group
- 4.3.9.2.5 <u>OS</u> Software The OS software package will consist of computer manufacturer supplied software and contractor developed software. The software will be divided into functional groups and modules to maintain easier control and development. The two major functional groups are Support software and Operational Software. (For a detailed description of software management, development, packaging, and test language, See Part D, Section 8, of this volume.)
- 4.3.9.2.6 <u>OS</u> Reliability The intended usage of the OS in the STC imposes multipurpose, on line, real time, time sharing requirements that demand continuous operation, faster response, reduced maintenance times, and a longer mean time between failure (MTBF). These requirements can be met only by adhering to the highest levels of design, production, and operational reliability. The candidate OS manufacturers must demonstrate that their products will, as a minimum, meet the following constraints in addition to the P_s assigned as a result of Phase C Reliability analyses.

a. Design Reliability

- o Proven Components and Vendor Selection
- o Maximum Use of Integrated Circuits and Solid State Devices
- o Modular Construction
- o Proven Circuits and Worst Case Design
- o Power Transient Control
- o Product Verification Tests

b. Production Reliability

- o Engineering Manufacturing Design Reviews
- o High Reliability Production Methods
- o 100% Testing of Active Elements
- o Sub-system testing in Production
- o In-depth quality planning

c. Operational Reliability

- o Pyramid and Staircase Diagnostics
- o Field Engineering Product Evaluation
- o Preventive Maintenance Procedures
- o Field Quality/Reliability Reporting

The greatest deterrents to ODS operational reliability are input power

transients that may affect its sub-systems. Component derating and conservative circuits cannot protect systems from all transient stresses that may cause failures. Protection must come from power system control. Accordingly, the CDS will have as a minimum, the following power transient protection and control features:

- o A means of protecting the CDS core memory content during power-on and power-off events, whether the transients are initiated intentionally by the operator, or induced accidentally by power line or other disturbances
- o A means of preserving the status of the CDS CPU (during power-up and power-down transients) with sufficient completeness to enable an interrupted program to restart automatically if desired from the point it was interrupted, regardless of the duration of power failure.
- o A means of protecting the Rapid Access Data Storage System (disc) memory from accidental erasure or erratic over-writing during power-up and power-down transients.

4.3.9.2.7 <u>OS Candidates</u> - Selection of a candidate, or group of candidate CDS's during this phase of the study has been limited to the selection of a functional group of computers. A trade study that supports this selection is presented in Part D, Section 10 of this volume. This study shows that the Functional Group of Computers defined as "third Generation" is best suited for the CDS application.

In view of this, McDonnell has studied the requirements and constraints for the CDS and presently considers and Scientific Data Systems (SDS) Sigma 5, "Third Generation Computer" as a candidate for the CDS. The Sigma 5 meets all presently knwon requirements will meet the anticipated VOYAGER 1975 requirements, and provides maximum growth potential with a minimum of hardware and software changes.

4.3.9.3 Test Directors Console

- a. <u>Identification and Usage</u> The Test Director's Console is a three bay console assembly that provides the necessary controls, displays and communications to enable the Test Director to coordinate system test complex activities during the performance of Capsule Bus system tests.
- b. <u>Design Characteristics</u> The Test Director's Console is designed around a keyboard display assembly that directly interfaces with the CDS computer. The functional description in Section 4.3.9.2 describes the keyboard display assembly in detail. In addition to the computer interface, the console contains Capsule **Bus** emergency shutdown and hardline control and display functions required for STC control and coordination. Capsule

- Bus and STC test status signal transmission to the Launch Monitor Console in the LCC are also provided.
- C. <u>Physical Characteristics</u> The Test Director's Console is provided with slanted control and display panels, a desk top multipurpose keyboard display unit, writing surface and under the shelf panels containing CDS interface logic unit, display driver unit, voice frequency tone generators, dc power supply, storage drawer, cabinet blower and ac power control panel. Figure 4.3-10 illustrates the Test Director's Console.
- Operational Description The Test Director's Console is the central control point in the Capsule Bus STC. The keyboard is used to initiate test and fault isolation routines by sending instructions to the CDS computer and also to call up test data displays on the AN/CRT. Analog and discrete displays provide monitor capability for computer independent functions, with discrete emergency shutdown commands being initiated from a control panel as required. In addition, the console sends discrete signals to the LCC to keep the Launch Control Console operator aware of the status of the Capsule Bus and test progress. An intercom panel is used to maintain voice contact with each subsystem console and other operational positions, including remote support sites such as the Spacecraft and PV control room, ESF, Pad and DSIF 71. For either automatic or manual modes system testing, the Test Director's Console receives test request signals from the individual subsystem consoles, and generates test commands. The enable commands are interlocked with the Subsystem Consoles command circuit to positively prevent inadvertent or out of sequence command transmission. Digital timing displays provide continuous monitor of real time, test time and countdown time. Voice tone frequencies are used to transmit CB status to the CB Launch Monitor Console in the LCC.
- e. <u>Interface Definition</u> The major interfaces of the Test Director's Console are depicted in the block diagram, Figure 4.3-11.

4.3.9.4 Ground Data Transmission System

Equipment Identification and Usage - The Ground Data Transmission system (GDTS) is used to send commands from the System Test Complex (STC) to the remotely located Capsule Bus (CB) and OSE. This system also collects, formats, and transmits data from the remotely located equipment and Capsule Bus to the STC. One existing A2A and one telepone line are used to connect each romote site with the STC.

Design Requirements and Constraints - The GDIS is required to perform the following

TEST DIRECTOR'S CONSOLE

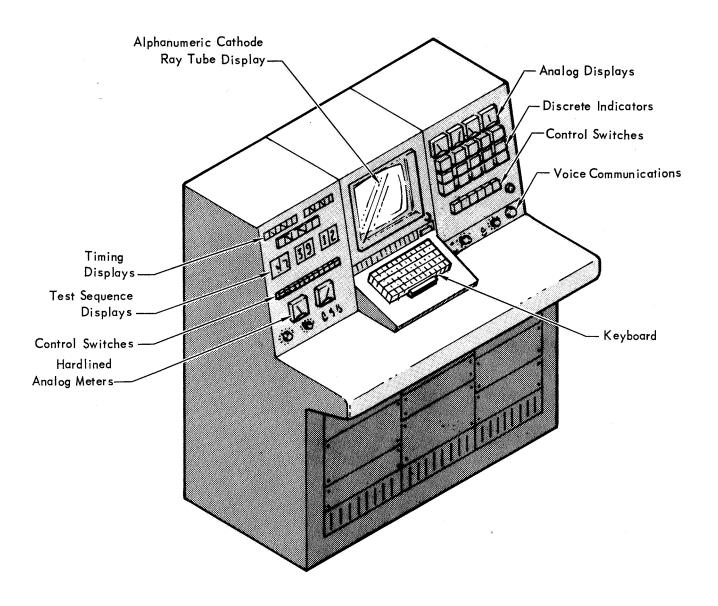
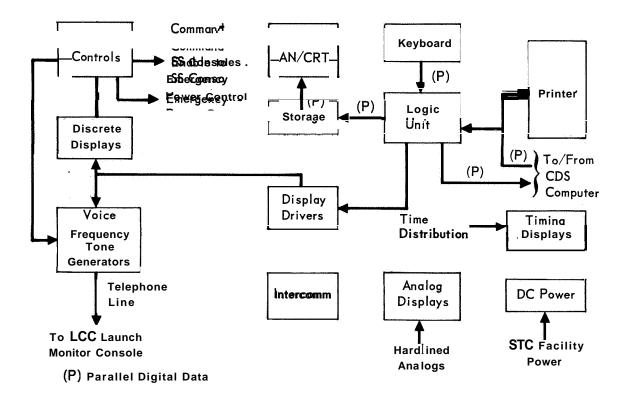


Figure 4.3-10

BLOCK DIAGRAM - TEST DIRECTOR'S CONSOLE



functions:

- 1. Digitize analog signals and multiplex these with bilevel and digital data at the CB.
- 2. Transmit the data with parity to the STC.
- 3. Format the received data for interface with the CDS and STC Consoles.
- 4. Format STC commands and transmit them to the CB vicinity using error control techniques.
- 5. Receive the commands at the CB and route them to the CB and CB vicinity OSE.

Physical Characteristics - The GDIS is contained in two standard cabinets as shown in Figure 4.3-12. The CB Terminal Unit is located in the test area adjacent to the CB and the STC Terminal Unit is located in the CB Contractor's control room. At KSC, the terminals are connected by the existing A2A link and a voice grade telephone line. For CB factory testing, the terminals are connected by coaxial cables.

Operational Description - The operation of the GDTS Is described in three parts: a) the Capsule Bus and vicinity OSE to System Test Complex data flow (downlink); b) the System Test Complex to Capsule Bus and OSE command flow (uplink); and c) command verification and self test.

The GDIS downlink - Functional block diagram is shown in Figure 4.3-13. CB and OSE test parameters are routed to the CB Terminal Unit for signal conditioning, multiplexing, digitizing, and transmission over the A2A link.

Analog dc voltage inputs are applied to a variable gain multiplexer. Conversion of other analogs (e.g. ac, phase, or resistance) to dc voltages is accomplished in the signal conditioner prior to multiplexing. Storage is provided for bilevel and digital word inputs. The timing generator provides clock signals to control the analog to digital converter, provide channel identification, control and data transfer from the inputs, and perform output formatting control. The formatter serializes the data, supplies synchronization patterns, and adds parity bits. The serial Pulse Code Modulated (PCM) time multiplex output is applied to a voltage controlled oscillator (VCO). The VCO output is a frequency shift keyed signal which is summed with VCO outputs from the following sources:

- o Radio frequency UHF link data (demodulated in the OSE UHF Receiving System).
- o The in-flight checkout PCM hardline output.
- o The cruise commutator RM hardline output.
- o The premodulated UHF link PCM hardline output.

GROUND DATA TRANSMISSION SYSTEM, UPLINK FUNCTIONAL BLOCK DIAGRAM

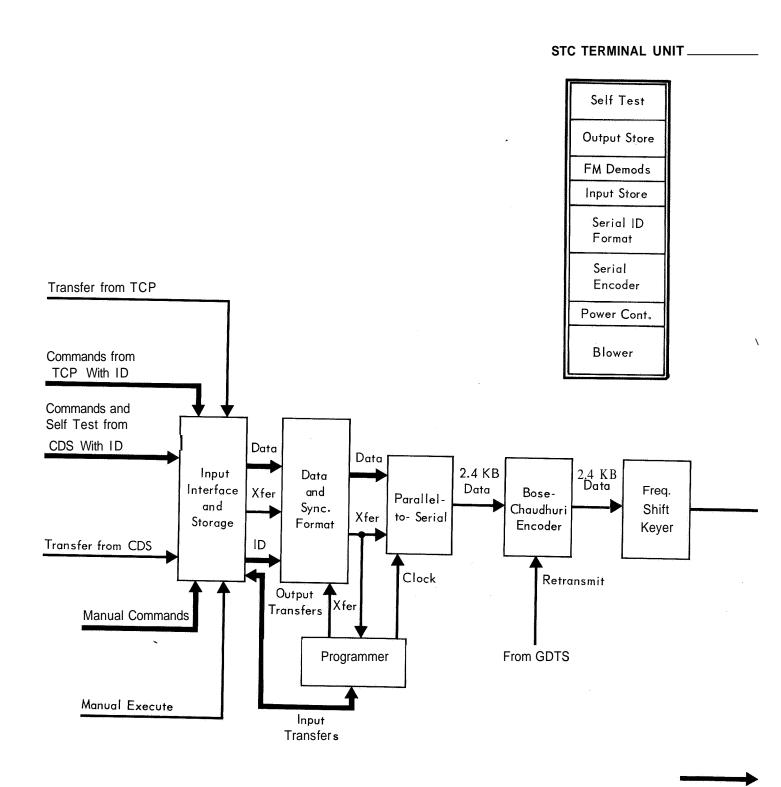
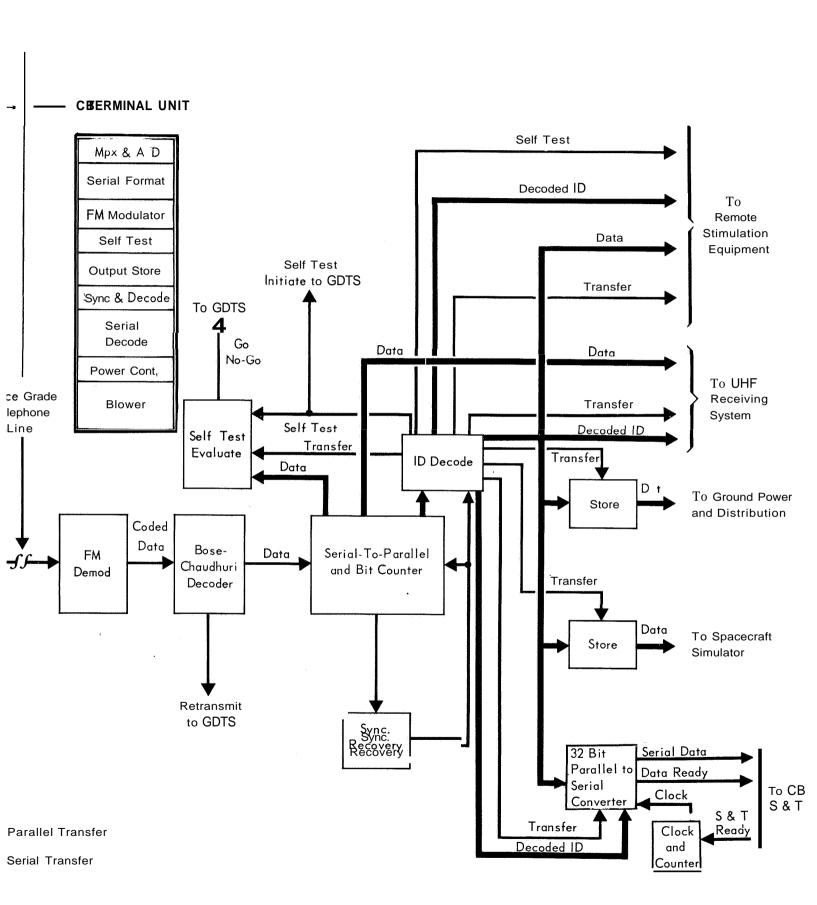


Figure 4.3-12

4-29 -1



4-29-2

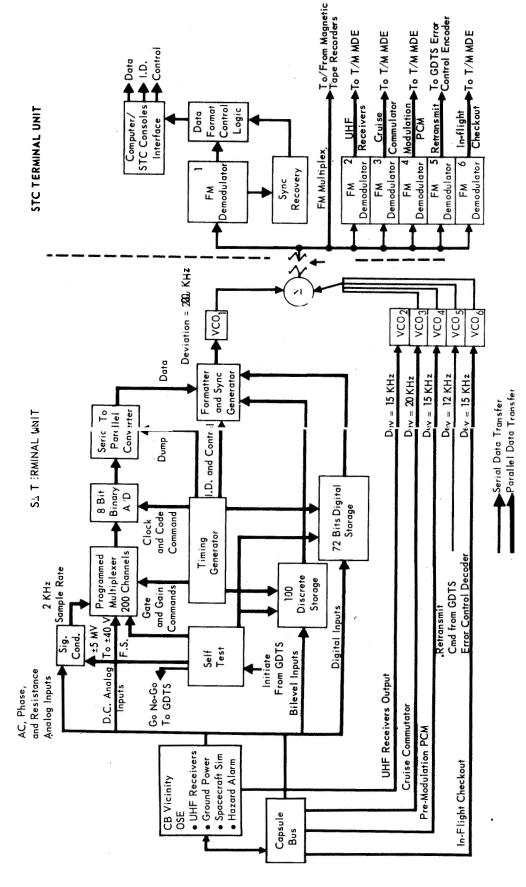


Figure 4.3-13

o The error control decoder retransmit signal.

The summed VCO outputs produce a 500 KHz bandwidth frequency modulation (FM) multiplex which is compatible with the A2A transmission line.

At the STC Terminal Unit, the FM multiplex is demodulated and routed as follows: The Telecommunications Subsystem PCM signals are sent to the STC-located Mission Dependent Equipment (MDE). The error control retransmit signal is sent to the uplink error control encoder. The demodulated time multiplex output is decoded by recovering synchronization checking parity and converting the data from serial to parallel. The data with ID bits is presented to the STC Computer Data System and Subsystem Consoles by use of an output storage buffer.

The GDIS uplink functional block diagram is shown in Figure 4.3-12. Test Commands and execute signals are accepted from the Computer Data System, the Telemetry and Command Processor and the Subsystem Console Manual Input Panels. The data is ID tagged and serialized with synchronization bits. The serial output is Bose-Chaudhuri error-control encoded and sent to a frequency shift keyer. The output bandwidth is 2400 Hz which is compatible with standard voice grade telephone lines. The CB Terminal $U_{\rm M}$ t decodes the Bose-Chaudhuri coding and if an error is detected, requests a retransmission via the downlink while inhibiting output of the erroneous command. The chance of an erroneous command being accepted by the decoder is 1.5×10^{-15} . The decoder output is converted to parallel format and synchronization is acquired. The ID decoder determines the data address, and an individual line from the decoder indicates each received address.

Parallel output is sent with decoded ID lines for remote control of the UHF Receiving System and the Remote Stimulation Equipment. Storage registers are provided for remote control of the Ground Power and Distribution Equipment, and the Spacecraft Simulator. Information for entry into the CB Sequencer and Timer (S&T) Subsystem is stored in a 32-bit parallel-to-serial converter and a data ready signal is sent to the S&T. Upon receipt of a S&T request signal, a clock and counter are used to serially output the 32 bits to the S&T subsystem.

<u>Command Verification and Self Test</u> - The requirement to prevent inadvertant test sequences or commands from being applied to the SL imposes stringent limits upon the performance of the GDIS and requires a means of command verification.

The use of the Bose-Chaudhuri encoding technique provides virtually error free command transmission. This cyclic coding method uses error detection and data re-transmission to achieve a bit error probability of 1.5×10^{-15} based on a transmission line bit error probability of 10^{-5} . The technique is effective for

single bit errors, multiple consecutive (burst) errors, and complete signal loss.

In this approach error control takes place prior to test stimuli application. In addition, stimuli relay positions (received commands) are monitored and automatically compared with the transmitted command by the Computer Data System.

This approach meets the requirement for low error command transmission in a manner which permits the use of existing land lines, with commercially available, field proven hardware and is selected as our preferred concept. Other command verification concepts studied during Phase B include techniques such as the "echo check" technique employed by the McDonnell-Douglas Saturn IV B ACS and the double command transmission method used by Apollo ACE.

Self rest is performed on both the uplink and downlink of the GDIS. For the uplink, the Computer Data System sends self test data words via the GDIS SIC Terminal to the CB Terminal Unit and these data words are compared bit-by-bit in the self-test evaluator. The CB Terminal data register inputs are inhibited so that the CB and vicinity using elements retain their previous inputs during self test. For the downlink, the CB Terminal Unit applies self test signals to all of its data inputs and the resulting output is transmitted to the Computer Data System via the STC Terminal Unit for evaluation.

After one complete data cycle, the self test inputs to both terminal units are removed and the system is again operational. In this manner, self test of the entire GDTS is performed in 250 milliseconds with minimum impact on the test in progress.

<u>Interfaces</u> - The interface of the GDIS with the Capsule Bus, STC, and other OSE during CB systems level tests is shown in Figures 4.3-12 (Uplink) and 4.3-13 (Downlink). During PV integration, the interfaces are similar, except that the OSE umbilical is not used after the PV shroud is installed.

4.3.9.5 STC Required Mission Independent Equipment (MIE) - The System Test Complex (STC) required MIE is an exact duplicate of the Telemetry and Command Processor (TCP) Computer and peripherals used at the Deep Space Instrumentation Facility (DSIF).

Telemetry and Command Processor (TCP) - The TCP is a high speed general purpose computer system that is normally used in the DSIF to provide flight commands and decommutated Capsule Bus telemetry data. The TCP is used in the Systems Test Complex to perform the same telemetry processing functions during Capsule Systems Test.

- a. Physical Characteristics The TCP presently consists of a Scientific Data Systems (SDS) 920 Computer System, a magnetic tape recorder group, 1/0 typewriter, tape punch, and tape reader. Because the SDS 920 Computer is a standard SDS product covered in the manufacturers literature, physical and operational characteristics will not be repeated herein.
- b. Functional Description The TCP translates capsule commands to the required format for capsule testing, and provides on-site data processing of telemetry signals (See figure 4.3-14 for TCP functional block diagram). The TCP acquires the de-interleaved capsule bus telemetry signals from the telemetry MDE. An interrupt line is used to indicate the presence of datum on an associated buffer. Data is read into memory through the parallel input. On executive program request, the data is transferred to a buffer area of memory where it is assembled into a word that includes a single character code associated with each individual data word. The decommutated, ID tagged data is then ready for 1/0 transfer to peripheral equipment and the STC Computer Data System. All capsule commands entered in the TCP are translated to the required formats, stored in memory, and transferred to the command MDE.
- c. Interfaces The TCP will interface with the following components (See Figure 4.3-14 for TCP interfaces)
 - o Telemetry MDE
 - o Command MDE
 - o STC Computer Data System (CDS)
 - o TCP Peripherals

TCP Peripherals - The TCP peripherals include the following equipment.

- o Magnetic Tape Recorder The recorder is used to store TCP processed telemetry and command signals for playback and future use.
- o Tape Punch and Tape Reader The punched tape equipment is used for assembling new programs, altering existing programs and loading the TCP memory.
- o Input/Output (I/O) typewriter The 1/O typewriter is used for operation

TELEMETRY AND COMMAND PROCESSOR (TCP) FUNCTIONAL BLOCK DIAGRAM AND INTERFACES

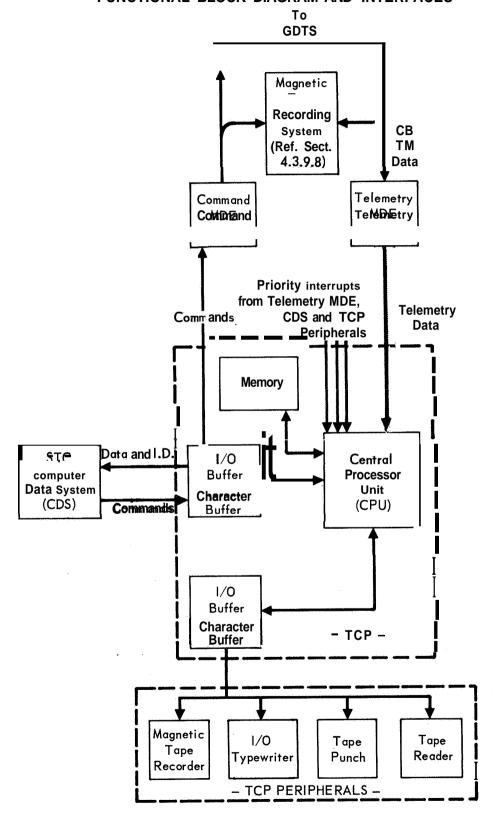


Figure 4.3-14 4-34

control, error and status message reporting, and simulation of Space Flight Operations Facility/Station Communications Processor (SFOF/SCP) communications with the TCP.

TCP Software — The TCP software used in the STC will be identical to that MDE software package developed for DSIF usage. This software will be developed early in Phase D, and will be used during initial Capsule Bus system testing at the CB contractor's facility to ensure early compatibility between the Capsule Bus and DSIF. The MDE software package for the TCP is described in Part D, Section 4.5.4 of this volume. Further details of software management, development, package and test language are described in Part D, Section 8 of this volume.

4.3.9.6 Simulators

Equipment Identification and Usage - Capsule Bus major modules and interfacing flight systems simulators are used to support module buildup and system testing. The simulators provide all required interface signals and loads to perform integrated testing prior to interfacing with the flight modules and systems. Thermal simulators are required for environmental testing of systems which have a thermal interface. ESP simulator requirements are based on ESP fabrication by a separate contractor; these will be revised when ESP technical management is determined.

Required simulators and their usage are:

<u>Simulator</u>	<u>Usage</u>
Canister and Adapter	At CB contractor's factory during module
	buildup and system test.
Capsule Lander	At CB constractor's factory for module
	buildup and system test.
CB to Spacecraft	Supplied to the Spacecraft contractor by
(Electrical & Thermal)	CB contractor; used in module buildup,
	system test, and environmental testing.
Spacecraft Mounted	Supplied to the Spacecraft contractor by
CB Support Equipment	CB contractor; used in module buildup and
	system test.
CB to ESP	Supplied to the ESP contractor by CB con-
	tractor; used in module buildup and system
	test.
	Canister and Adapter Capsule Lander CB to Spacecraft (Electrical & Thermal) Spacecraft Mounted CB Support Equipment

Simulator

f.	CB to SL	Supplied to the SL contractor by CB con-
	(Electrical & Thermal)	tractor; used in module buildup, system
		test, and environmental testing.
g.	Surface Laboratory	Supplied to CB contractor by SLS contrac-
	(Electrical & Thermal)	tor; used at CB contractor's factory dur-
	(GFE)	ing module buildup, system test, and en-
		vironmental testing.
h.	Entry Science Package	Used at CB contractor's factory during
	(Electrical & Thermal)	module buildup, system test, and environ-
	(GFE)	mental testing.
i.	Spacecraft	Supplied to CB contractor by spacecraft
	(Electrical & Thermal)	contractor; used during module buildup,
	(GFE)	system tests, and environmental testing

Usage

at the CB contractor's factory and at KSC.

<u>Physical Characteristics</u> - The electrical simulators are installed in standard electronic cabinets and grouped by using location. Power and cooling €or the simulators are integral to each cabinet.

<u>Functional Description</u> - Each simulator is described briefly as to its function in support of the SSTS and STC during test.

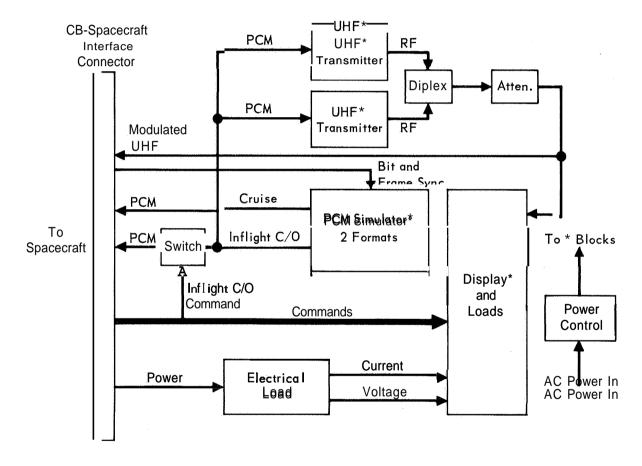
- a. <u>Canister and Adapter Simulator</u> This simulator provides manually selectable digital words and analog signals simulating the following Canister and Adapter functions; in-flight checkout subsystem commands and calibrate signals, telemetry data from thermal control, sequencer, power, pyros, cruise commutator, and pressurization and venting subsystems in the Canister and Adapter.
- b. <u>Capsule Lander</u> This simulator is functionally similar to the Canister and Adapter simulator. The loads and responses simulate the Capsule Lander functions.
- c. <u>CB to Spacecraft (Electrical and Thermal)</u> The CB to spacecraft electrical simulator provides the following capabilities:
 - o supplies loads for the spacecraft-generated commands and displays their receipt
 - o supplies loads for spacecraft power, and displays current and voltage levels

- o receives spacecraft bit and frame synchronization signals and generates synchronous cruise commutator and in-flight checkout PCM data.
- o switches on the correct PCM data when directed to by spacecraft command
- o generates two UHF modulated RF outputs for simulation of the CB in-flight checkout. UHF signal strength is variable and its magnitude is displayed. A functional block diagram of the CB to spacecraft simulator is shown in Figure 4.3-15.

The CB to Spacecraft Thermal Simulator performs two distinct functions during environmental testing. The first is to simulate the CB thermal characteristics to the spacecraft. This includes heat transferred by radiation through the aft surface of the CB Canister and that transferred by conduction through the adapter structure. The second is to simulate the CB aft canister and adapter for post separation thermal testing of the spacecraft.

- d. <u>Spacecraft Mounted CB Support Equipment</u> This simulator supplies signals which simulate the output of the CB data storage subsystem which is located in the spacecraft. Additional signals simulate Spacecraft mounted CB status data. Loading is supplied for spacecraft-to-CB commands and display is provided for verification of command receipt.
- e. <u>CB to ESP</u> Synchronization signals and PCM are supplied to the ESP telemetry system for checking the ESP data interleaver by this simulator. Simulated events such as touchdown are supplied as well as discrete in-flight checkout signals.
- f. CB to SLS (Electrical & Thermal) The electrical simulator supplies DC power, in-flight checkout commands, and a touchdown signal to the SL. The CB to SL Thermal Simulator is used for SLS thermal testing. It simulates the CB thermal properties (radiation and conduction) thus providing a means of evaluating the SLS under mated conditions.
- g. <u>Surface Laboratory (Electrical & Thermal) Simulator (GFE)</u> The Surface Laboratory Electrical Simulator accepts the touchdown signal and the inflight checkout commands from the Capsule Bus and display verification of their receipt. Electrical loading is provided for the CB supplied SL power with display of current and voltage magnitude. The SL Thermal Simulator provides a thermal interface that represents the conductive and radiative characteristics of the SL for use during CB factory environmental testing.

CB TO SPACECRAFT ELECTRICAL SIMULATOR - BLOCK DIAGRAM



- h. Entry Science Package (Electrical & Thermal) Simulator (GFE) The ESP Electrical Simulator provides the required loads and responses to the Capsule Bus. It contains a Telecommunications Subsystem simulator which accepts the Capsule Bus synchronization signals, and provides a simulated data output for checkout of the CB interleaver. The ESP Thermal Simulator is similar in function and usage to the SL Thermal Simulator described above.
- Spacecraft (Electrical & Thermal) Simulator (GFE) The Spacecraft Electrical Simulator will provide an electrical path from the CB Ground Data Transmission System (GDTS) to the capsule bus for commands, cruise commutator, and in-flight checkout data. The simulator supplies data synchronization signals to the CB Telecommunications Subsystem. The Spacecraft Thermal Simulator is similar in function and usage to the SL Thermal Simulator described above.

4.3.9.7 Special Purpose STC Equipment

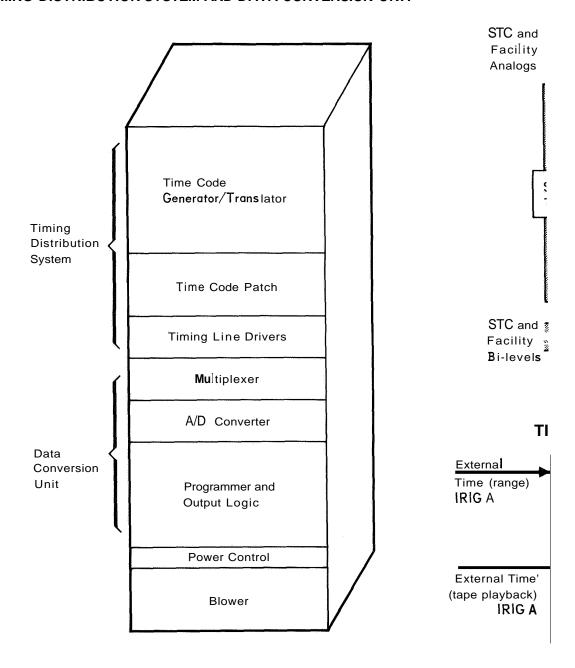
<u>Equipment Identification and Usage</u> - The Special Purpose SIC Equipment completes the operational functions of the SIC with following major end items:

- a. Data Conversion Unit
- b. Timing Distribution System
- c. Magnetic Tape Recording System
- d. Strip Chart Recorder Group
- e. Mobile Maintenance Cart
- f. Voice Communication System
- g. Complex Cabling
- h. Pyrotechnic Test Kit
- i. Junction Box
- i. TV Monitor (GFE)
- k. Countdown Timing & Display (GFE)

Each of the above end items is described below.

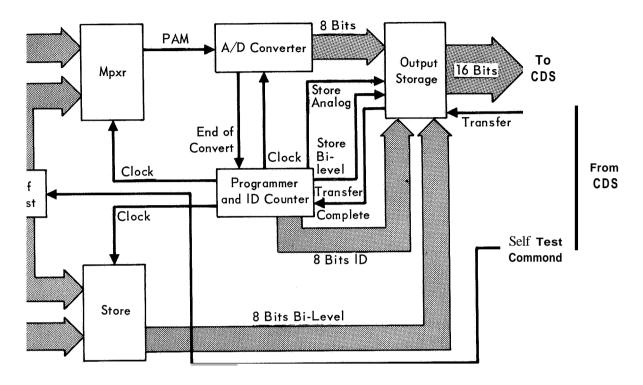
- a. Data Conversion Unit
 - o <u>Desipn Requirements and Constraints</u> The Data Conversion Unit is required to convert STC OSE, facility, and external instrumentation data to a digital format compatible with the CDS computer.
 - o <u>Physical Characteristics</u> The Data Conversion Unit consists of three panels mounted in a standard cabinet with the Timing Distribution System as shown in Figure 43-16.

TIMING DISTRIBUTION SYSTEM AND DATA CONVERSION UNIT

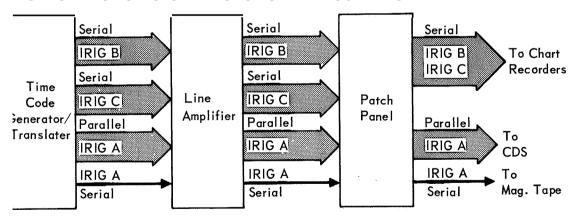


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DATA CONVERSION UNIT FUNCTIONAL BLOCK DIAGRAM



ING DISTRIBUTION SYSTEM FUNCTIONAL BLOCK DIAGRAM



igure 4.3-16

4

- Operational Description The Data Conversion Unit converts OSE, facility, and external instrumentation analog signals into digital form, and multiplexes these with bilevel parameters in a format compatible with the CDS computer input/output controller. The converter input data in various forms is digitized into 8 bit words, tagged with 8 ID bits and stored in parallel until called for by the CDS 1/0 controller as shown in Figure 4.3-16. When the transfer of data from the Conversion Unit to the CDS is complete, the Unit advances to the next 16 bits of data and address. Thus, the sample rate is dependent on the data transfer rate to the CDS. When the CDS processing load is relatively small, the Data Conversion Unit sample rate is higher. Self test is performed upon command from the CDS by switching the multiplexer and bilevel storage to a calibrated input while the outputs are monitored by the CDS.
- o <u>Interfaces</u> The Data Conversion Unit interfaces with STC Control Room OSE end items, a CDS input/output controller, and facility data, as shown in Figure 4.3-16. In the LCE configuration, Launch Vehicle data and external instrumentation parameters will also interface with the converter. The Data Conversion Unit is readily available commercially off-the-shelf, with no development risk, low cost and proven reliability.

b. Timing Distribution System

- <u>Design Requirements and Constraints</u> The Timing Distribution System is required to provide test data correlation to one millisecond.
- o <u>Physical Characteristics</u> The Timing Distribution System consists of three panels mounted in a standard cabinet with the Data Conversion Unit as shown in Figure 4.3-16.
- o Operational Description The Timing Distribution System operates from either a self generated time code or an external time code input. Time information is distributed to the required STC elements in a suitable format as shown in Figure 4.3-16.

The Time Code Generator/Translator is a high stability time code generator which may be synchronized to an external time code input such as range time, or operate independently when range time is not available or fails for any reason. The Generator provides a parallel IRIG A (1000 pps) time code output, which is routed to the CDS for time reference to 1 millisecond. In addition, a serial IRIG A output provides a

time reference to the Magnetic Tape Recorders. Two slow code ouputs are provided for the strip chart recorders. Each generator output is amplified by a line amplifier to a voltage that is compatible with the using device. A Patch Panel is used for code selection and for switching to a backup amplifier in case of a line amplifier failure.

O Interfaces - The Timing Distribution System interfaces with the CDS, Magnetic Tape Recording System, and Strip Chart Recorders, as shown in Figure 4.3-16. At KSC, the external time code input will be range time, thus insuring that the STC time is synchronized with other PV contractors.

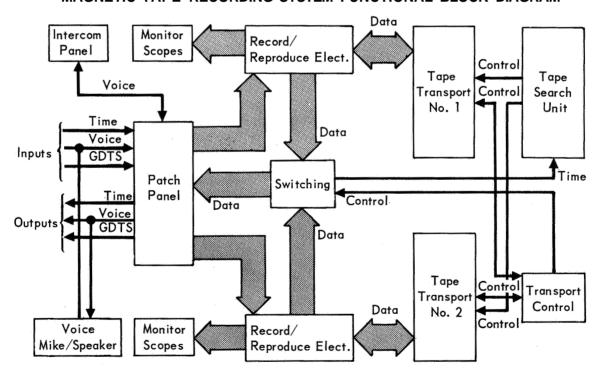
c. Magnetic Tape Recording System

- o <u>Design Requirements and Constraints</u> A magnetic tape recording of STC and CB video and audio signals (i.e. Ground Data Transmission System multiplex, time, and voice) is required for off-line analysis by the STC or in case of STC malfunction.
- o <u>Physical Characteristics</u> The Magnetic Tape Recording System is housed in three standard cabinets as shown in Figure 4.3-17.
- o Operational Description The Magnetic Tape Recording System contains two magnetic tape transports with direct and frequency modulated record/reporduce electronics. Figure 4.3-17 is a functional block diagram of the System. Inputs and outputs are wired to the patch panel and patched to the record electronics and data switch. The switch connects the reproduce outputs of either recorder to the patch panel in the reproduce mode. Inputs are applied to both record electronics at all Reproduce electronics are operating continuously, for playback or record monitor. The frequency response of the recorders is flat to 750 KHz at 60 in. per sec. The transport control provides automatic start of the empty recorder as the full recorder nears the end of the tape. The tape search unit provides the logic to locate a portion of a recorded tape during playback by searching for a particular time on the tape. The monitor panels each contain 7 small oscilloscopes which monitor every channel input or output. Capability is provided for recording or reproducing intercom conversation on an intercom network.
- o <u>Interface</u> The Magnetic Tape Recording System interfaces with the Timing Distribution system, the Ground Data Transmission System, and the Voice Communication System as shown in Figure 4.3-17.

MAGNETIC TAPE RECORDING GROUP

_	Tape Search			
Tape Transport	Trans. Switches Control		Tape Transport	
	Patch			
Monitor	Panel		Monitor	
Rec/Reproduce	Intercom		Rec/Reproduce	
Electronics	Voice	Power	Electronics	
Blower	Blower		Blower	

MAGNETIC TAPE RECORDING SYSTEM FUNCTIONAL BLOCK DIAGRAM



d. Strip Chart Recorder Group

- Design Requirements and Constraints Thirty two channels of analog recording and 100 channels of discrete function recording are required to support systems testing. The recorders accept analog voltages and discrete inputs from the CDS. Time codes are recorded to permit data reduction time correlation.
- o <u>Physical Characteristics</u> The Strip Chart Recorder Group is mounted in three standard cabinets as shown in Figure 4.3-18.
- Operational Description Figure 4.3-18 shows a functional block diagram of the Recorder Group. Digital-to-Analog Converter outputs from the CDS Computer are wired to the patch panel inputs. Slow (1 pulse per minute) and fast (2 pulses per second) time codes are also provided as patch panel inputs. Eight analog signals and two timing signals are patched to each recorder. The recorders are rectilinear, ink-type with pen position feedback. Their frequency response is dc to 50 Hz.

Bilevel parameter sets with ID bits are sent from the CDS 1/0 device to the ID decoder in the Recorder Group in 8 bit parallel groups. Manual switches control the decoder which selects the bilevel sets (ID) and bilevel parameter of the set to be recorded. When a desired ID is decoded, the selected bits are transferred to the bilevel storage. The storage outputs are hardwired to the bilevel recorder. The recorder type is 100 channel electric write. Time signals are routed to the extreme left and right right styli.

Recorder group operation is verified by programming known inputs (analog and bilevel) from CDS. The recorder operator can then verify the correct operation of each channel. Local switches provide an operational check by applying a known input on individual channels as required.

o <u>Interfaces</u> - The Strip Chart Recorder Group interfaces with the CDS computer for inputs as shown in Figure 4.3-18.

e. Mobile Maintenance Cart

o <u>Design Requirements and Constraints</u> - For System Test Complex (STC) setup, maintenance and troubleshooting, limited mobile test equipment is required.

STRIP CHART RECORDER GROUP

	/	/	
Analog	D.F. Recorder	Analog	
Recorder	D.F. Decoder	Recorder	
Analog	Patch Panel	Analog	
Recorder	Intercom	Recorder	
Power Control	Power Control	Power Control	
Blower	Blower	Blower	

FUNCTIONAL BLOCK DIAGRAM STRIP CHART RECORDER GROUP

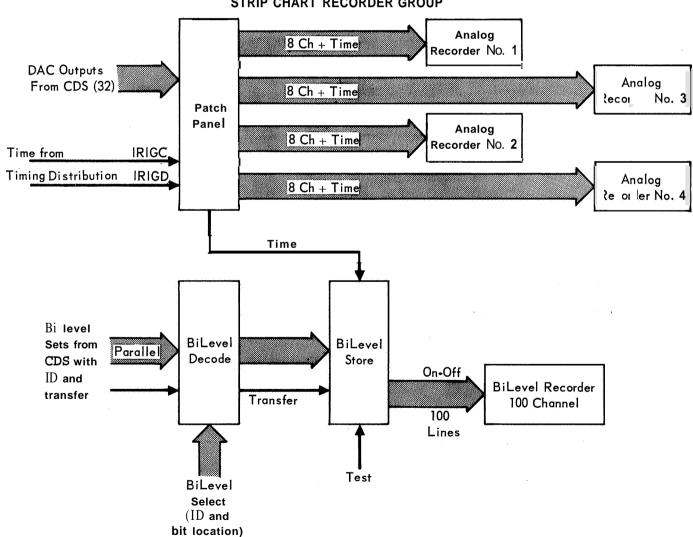


Figure 4.3-18

- O <u>Physical Characteristics</u> The test equipment is mounted with power control and protection in a caster equipped cart. Size is limited to permit mobility to any location on the STC.
- Operational Description The test equipment installed in the cart is itemized below:
 - a. Dual Beam Oscilloscope with delayed sweep, differential and high gain plug-ins, and camera.
 - b. Digital voltmeter with dc, ac and resistance capability.
 - c. Voltage calibrator with dc and ac of variable frequency.
 - d. Pulse generator.

f. Voice Communication System

- o <u>Design Requirements and Constraints</u> A communication system is required among all elements of the STC; the STC and Launch Control Center, launch pad, Planetary Operators Control Center, and any remote support areas. Public address access and commercial telephone interface equipment is also required.
- o <u>Physical Characteristics</u> The Voice Communication System consists of the Voice Communication System Control Rack and individual remote panels located in the STC Consoles and operator locations as required.
- Operational Description Each Remote Intercom Panel services two headsets. Available at each panel are 3 complex/remote location networks, 2 commercial telephone lines, and a P.A. access line. The Control Rack contains a patch panel for connecting the remotes to the various intercom networks. A total of 6 intercom nets are provided so that special purpose nets may be patched as required. All the remotes are wired directly to the control rack to provide a centralized interface with other communications equipment. Network and hardware redundancy are used in case of malfunction.
- o <u>Interface</u> The remote panels interface physically with their rack location. The control rack interfaces with facility intercom, facility P.A. system, and commercial telephone system. Voice communication with other Space Vehicle contractors is via the facility intercom network.

g. Complex Cabling

Design Requirements and Constraints - Cables are required to interconnect
the Capsule Bus OSE, connect OSE to other interfacing systems and connect
OSE to the Capsule Bus for systems testing at the factory and KSC.

Operational Description - Each STC includes its own set of cables which are transported and installed at KSC prior to the arrival of the STC. Subflooring, cable trays, etc., are configured to provide easy access for installation and removal of cables within the STC. Power distribution cables and associated junction boxes are provided at each OSE site. At KSC, additional cabling is supplied for use on the pad, at the ESF, and at PV integration. Standard 19 gage leased phone lines between the STC and LCC are used for transmission of data related to Capsule Bus and STC status. Use of A2A wideband data cables between the STC and pad for Capsule Bus Hazard Alarm and monitor, are subject for negotiation during the Hardware Acquisition Phase.

Since the STC cabling is moved periodically, particular attention has been given to the cabling approach to prevent incorrect connector mating, control grounding paths, insure single point shield grounds, and size conductors appropriately for all STC configurations. Sufficient spare conductors are included for a 10% growth. Computerized techniques are used for control of cable configuration and changes. Automatic cabling ring-out equipment is used to insure rapid, accurate checkout prior to STC connection on all locations.

h. Pyrotechnic Test Kit

- o <u>Design Requirements and Constraints</u> The Pyrotechnic Test Kit is used during installation of electroexplosive devices (EED's) to measure pyro firing circuits, including the EED bridge wire resistance. The resistance measurements are performed again after terminal sterilization to verify that no degradation has taken place.
- o Operational Description Pyro firing circuits are tested not only for continuity, but ability to deliver the necessary 100% fire current into simulated EED load impedance in the test kit. Stray voltage measurements from dc into the RF region are made both the firing and EED circuits to insure safety.

The Pyrotechnic Test Kit is a portable unit containing a resistance bridge, low voltage battery power supply, simulated loads, wide frequency range voltmeter, and a control panel on which are mounted the necessary switches and displays and cable adapters.

i. Capsule Bus Junction Box

- o <u>Design Requirements and Constraints</u> The Capsule Bus Junction Box is required to provide Capsule Bus signal distribution and OSE cable connections during systems testing at the factory and KSC.
- Operational Description The Capsule Bus junction box will be provided at each test area to distribute analog, digital and bilevel Capsule signals. Signal conditioning equipment will be provided at the J/B as required to insure adequate transmission of low level signals over extended cable lengths.
- 4.4 LAUNCH COMPLEX EQUIPMENT (LCE) The LCE is required to expeditiously test the CB on-pad and determine its readiness to meet the mission requirements. By using the CB TCM link, supplemented by a limited number of hardlines from the S/C flyaway umbilical, and using the corresponding portion of the System Test Complex and Mission Dependent Equipment for the LCE function, this requirement is met. The CB in-flight checkout mode and the STC/LCE with its built in test capability, will rapidly identify the nature of a malfunction within the CB or OSE. This ability is essential in deciding to commit to launch or recycle.

LCE must also 'perform reliably during the critical launch operation. The LCE, including those STC elements used in LCE, must demonstrate the reliability goals to be assigned. The MDE used will have reliability equal to or greater than the LCE requirements. The choice of critical CB and OSE launch parameters to be monitored by the LCE will be made during Phase C. This is being implemented by failure mode and reliability analysis, and a computerized math model of the CB and LCE equipment and pad operations. This investigation will provide these results:

- a. Determination of the critical CB parameters to be brought out the S/C flyaway umbilical.
- b. Critical LCE parameters to be monitored by the STC, and by hardlined analog to the LCC and Hazard and Alarm Monitor System.
- c. The required MIBF for LCE (including those STC elements used for the LCE function).
- d. Identification of those LCE elements requiring redundancy to meet the Voyager probability of success of on-time launch.
- 4.4.1 <u>Requirements & Constraints</u> The LCE has both CB Contractor and customer derived requirements and constraints which must be met. Those having major impact on LCE design are listed on the following page:

- o Complete testing of the Flight Capsule, as provided by the Capsule umbilical and RF test circuitry.
- o Provide for limited Capsule testing during RF silence.
- o Manually control the Capsule by the provided test circuitry.
- o Isolate trouble to the Capsule.
- o Automatically control the Capsule in the terminal portion of a simulated or real countdown with manual hold and reset capability.
- o Supply external Capsule power and power switching control.
- o Provide the necessary power distribution to minimize the main power distribution requirements in the Launch Control Center.
- o Provide for controlled transfer to emergency main power sources.
- o Provide for main power isolation from launch facility loads.
- o Provide for conditioning the Capsule to a safe mode in event of failure and subsequent resumption of facility power.
- o Provide continuous indications, controls and alarms, with or without Capsule or facility power on, of all Capsule or ground functions related to Capsule or personnel safety; e.g., pyrotechnic "arm-safe," propellant and gas pressures, or battery voltage.
- o Provide sufficient safeguards to prevent the occurrence of damage attributed to improper sequencing because of test steps and LCE element failure.
- o Provide a communication system between the Launch Control Center, launch pad, and the Planetary Operations Control Center.
- o Self-test without interruptions of Capsule operation.
- o Provide an operational reliability consistent with the launch probability of success.
- o Decoding, recording, time tagging, and displaying, independent of other data control centers of:
 - a. All Capsule inputs supplied by the LCE.
 - b. All Capsule data available at the launch complex.
 - c. All facility supplied power to the LCE.
 - d. All signals supplied to or from all other interconnecting equipment; e.g., interfacing functions to or from the launch vehicle system.
 - e. All external instrumentation data; e.g., outside temperatures or air conditioning inlet functions to or from the launch vehicle system.
 - f. Synchronizing signals from facility and ETR time codes.

The LCE which satisfies these constraints is described in the following paragraphs.

- 4.4.2 <u>Equipment Identification List</u> LCE can be divided into these functional groups:
 - O Ground Power and Distribution A two-bay cabinet providing automatic switching to facility back-up power, emergency back-up power in case of total facility power failure and dc power to the CB. This equipment is located in the base of the Mobile Launcher (ML) and at the ESF.
 - Remote Stimulation Equipment Test signal generation equipment used to provide stimuli required for on-pad testing of the CB.
 - O <u>UHF Receiving System</u> Provides UHF receiving equipment on the ML which demodulates the CB UHF transmitter output, brought out the S/C flyaway umbilical from parasitic antennas in the canister, for transmission of the CB TM data to the STC over the Ground Data Transmission System (GDTS). Spectrum and power-output measurements are made from equipment in the Mobile Launcher base.
 - o <u>LCC Equipment</u> A console in the LCC which has direct hardline access to the CB through the S/C umbilical for critical monitoring and commands. CB subsystem status, sent from the STC is also displayed here.
 - o <u>LCE Required STC Equipment</u> That STC equipment, including the CDS and MDE, required for on-pad testing of the CB. Test point access is by the TCM and the Spacecraft flyaway umbilical.
- 4.4.3 Operational Description The LCE, shown in the block diagram of Figure 4.4-1 provides these operational features:
 - a. Use of the STC and MDE (refer to paragraph 4.3.2 for description) for automatic monitor and evaluation of data from the CB.
 - b. Transmission of CB hardline data and commands between the CB and STC, using the GDTS.
 - c. Critical data and commands to the LCC on individual hardlines for monitoring and controlling critical parameters, such as power and temperatures.

Use of the STC in the LCE function provides a continuation of the test data log started in early STC testing, and provides test continuity in equipment, procedures, and operating personnel.

- 4.4.4 <u>Reliability and Safety</u> Besides those reliability and safety features provided by the STC, additional requirements imposed by pad operations are met by the LCE.

 These are:
 - o <u>Hazard and Alarm</u> Detection of CB propellant leakage and automatic power shut-down.

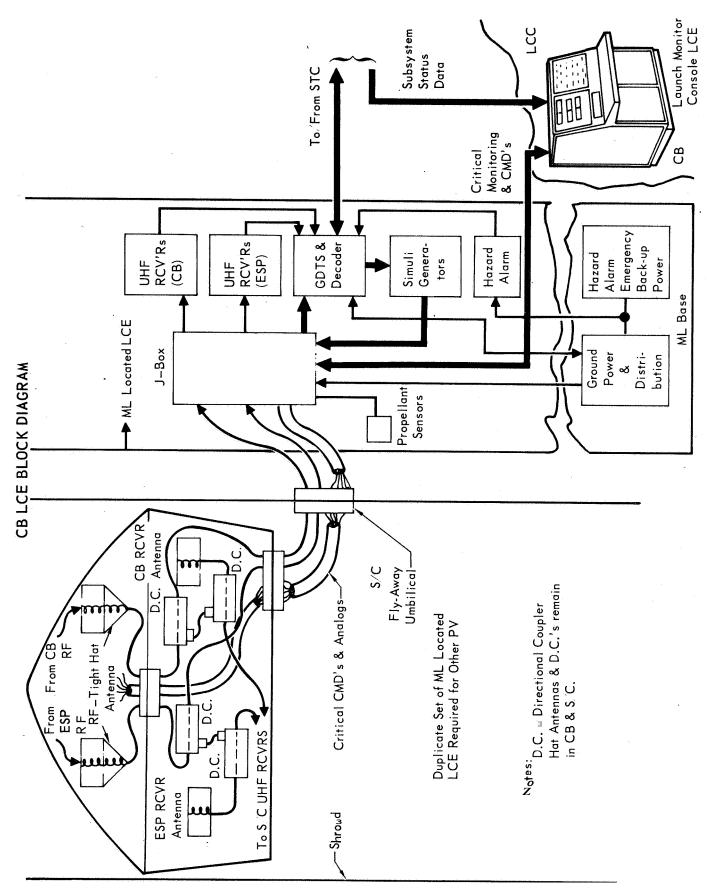


Figure 4.4-1

- <u>Back-up Facility Power</u> To prevent test interruption in case of primary power failure.
- <u>Emergency Back-up Power</u> For monitoring critical CB parameters, and sequencing the CB subsystems to a safe condition in event of total facility power.

The various elements of LCE will be examined analytically early in the design phase; and the LCE will be tested on a system basis to demonstrate the assigned $P_{\rm S}$ as previously discussed in Section 4.4.

- 4.4.5 <u>Interface Definition</u> Figure 4.4-1 shows the Interface of LCE with the Pad 39 complex and facilities.
- 4.4.6 <u>Physical Characteristics</u> Figure 4.4-2 shows the proposed layout of the LCE, at Pad 39A, and the LCC, with the various equipments identified.
- 4.4.7 <u>Development Status</u> No major problems are anticipated in LCE development. Software developed for use in the STC CDS computer will be essentially identical to that required for LCE use, and facilities will be demonstrated with the CB proof test model.
- 4.4.8 <u>Equipment Functional Description</u> The LCE equipment groups identified above are functionally described in detail below, along with preliminary designs.

4.4.8.1 Ground Power and Distribution

- Identification and Usage The Ground Power and Distribution equipment is a two-bay cabinet-mounted assembly providing dc ground power to the Capsule Bus during systems testing at the contractor's factory and at the CB test facilities including SCF, ESF and Pad 39. It also provides ac facility power control and distribution for OSE located at the above sites.
- Obesign Requirements dc Power The Ground Power and Distribution equipment is designed to include the following provisions:
 - a. Provide 27.5 ± 1 VDC to the Capsule Bus during ground test operations.
 - b. Provide power to charge flight batteries and provide simulated loads to the batteries for charge/discharge cycling.
 - c. Simulate flight battery power including controlled voltage discharge based on watt-hour consumption.
 - d. Operate under control of the Hazard Alarm and Monitor System and the STC.
- Design Requirements ac Power The ground power and distribution equipment is designed with the following ac power provisions:
 - a. Distribute facility ac power to OSE used at all support areas including remote test areas at the CB contractor's plant and at KSC pad, ESF and SCF sites.

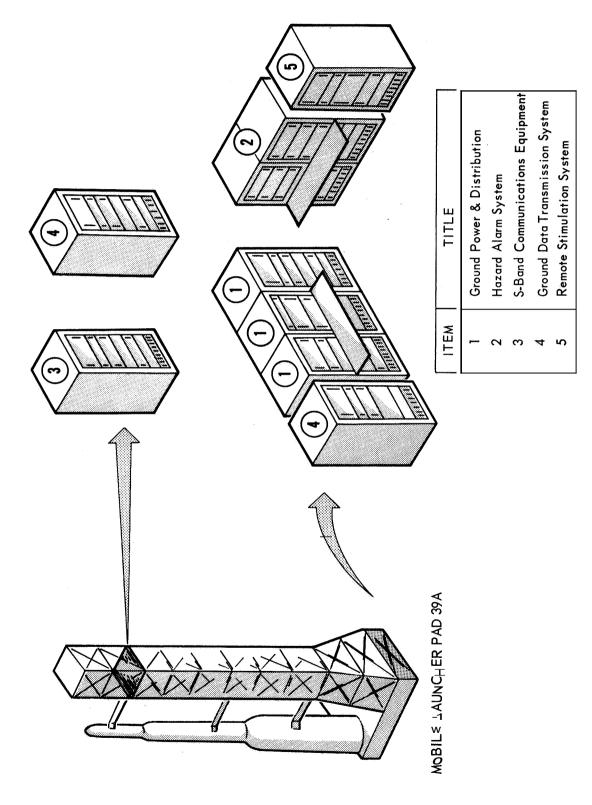


Figure **4.4–2**

- b. Provide instrument (regulated) ac power to OSE as required.
- c. Monitor and provide alarms for out-of-tolerance conditions of main KSC facility power and launch complex power with automatic transfer to emergency main power.
- d. Isolate the CB OSE loads at the pad from other facility loads by use of separate circuit breakers and distribution transformers as required.
- e. Operate in conjunction with the Hazard Alarm and Monitor System at the ESF and launch pad during emergency conditions requiring power shutdown.
- f. Operate under STC control.
- o Physical Characteristics The ground power and distribution equipment is mounted in standard electronic equipment cabinets and includes control and display panels, programmable dc power supplies, switching units, limit sensing electronics, strip chart recorder and ac regulator as illustrated in Figure 4.4-3. The dc power supplies, including the back-up supply, are of off-the-shelf designs incorporating line and load regulation, automatic overload protection for both the power supply and the Capsule. Remote sensing of supply voltage at the Capsule to compensate for line losses incurred from extensive cable lengths is also included.
- Operational Description The equipment supplies dc power to the Capsule Bus and ac power to associate OSE during system level tests at the factory and at KSC remote support areas with remote control by the STC, which monitors and controls the outputs. The equipment may also be controlled by the CB Launch Monitor Console in the LCC via hardlines. In addition, the Hazard Alarm and Monitor System automatically supplies emergency shutdown control. Manual controls and monitors are built in for local operation.

Pyro bus voltage and arming circuit monitoring is provided by the Hazard Alarm and Monitor System, described in paragraph 4.4.8.5.

o <u>Performance Characteristics</u> - The equipment includes electronic limit sensing that automatically monitors both ac and dc power, detects deviations beyond preset limits, and generates both audible and visual alarms locally and transmits alarm signals to the STC. Fault isolation to the

GROUND POWER AND DISTRIBUTION EQUIPMENT

AC POWER	DC POWER	
Sensing Unit	Sensing and Switching Unit	
Displays	Displays	
Controls	Controls	
Intercomm	Console AC Power	Recorder
Switching Unit	Power Supply No. 1	
D	Power Supply No. 2	
Regulator ,	Back Up Power Supply	
Blower	⁻ Blower	

replaceable unit level is achieved by identification of the malfunction—ing power supply or facility source found to be in error. The electronic limit sensing circuitry has a self test mode that cycles test signals in—to the limit detectors to verify detector performance.

The dc power supplies may be programmed by the $C\!D\!S$ for CB performance margin testing.

- o <u>Interface Definition</u> The interfaces of the Ground Power and Distribution unit as shown in the functional block diagram of Figure 4.4-4 and 4.4-5 include:
 - a. Facility Power KSC Power, Pad Power and Emergency Power
 - b. Ground Data Transmission System STC controls and data functions
 - c. Hazard Alarm and Monitor System emergency shutdown
 - d. Capsule Bus ground dc power
 - e. Launch Monitor Console backup control and monitor functions
 - f. Intercom -, voice communication with controlling elements (STC, LCC).

4.4.8.2 Remote Stimulation Equipment

- o Equipment Identification and Usage This equipment provides a remotely controllable source of test stimuli to the CB as required to support systems testing at the factory and KSC.
- o <u>Design Requirements and Constraints</u> The Remote Stimulation Equipment is required to apply the following test stimuli to the CB: A.C. Voltages, D.C. Voltages, and resistive loads. The equipment operates under remote digital control from the CDS computer via the Ground Data Transmission System (GDTS).
- o <u>Physical Characteristics</u> The Remote Stimulation Equipment is mounted in a single standard cabinet as shown in Figure 4.4-6. It is located near the CB in all system test configurations.
- o Operational Description The Remote Stimulation Equipment receives commands with identification lines from the GDTS. The equipment actuates a relay for each command received which controls the application of the selected stimulus to a CB test point. A functional block diagram of the equipment is shown in Figure 4.4-6.

FUNCTIONAL BLOCK DIAGRAM DC POWER CONTROL

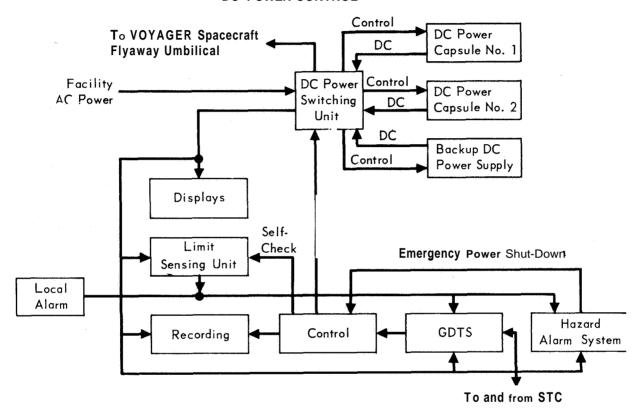
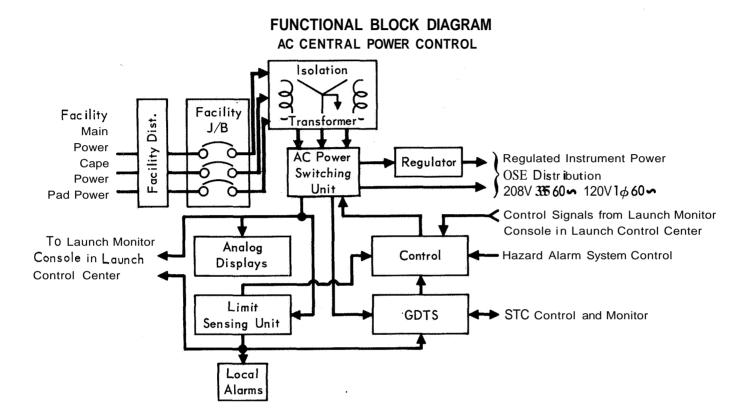
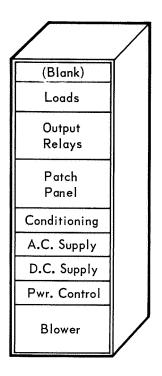


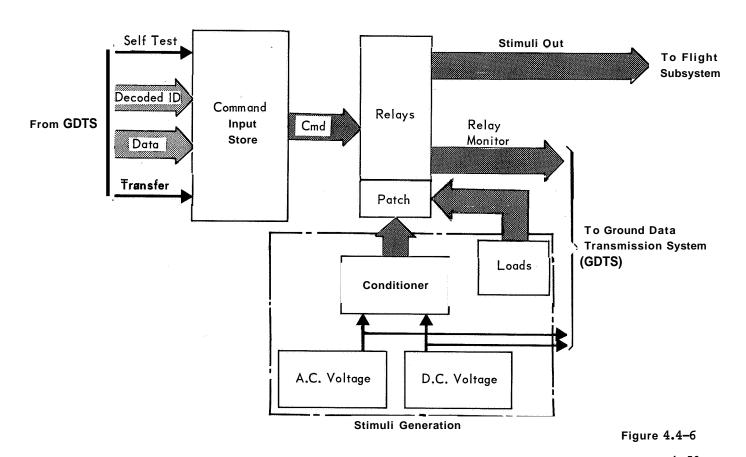
Figure 4.4-4



REMOTE STIMULATION UNIT



REMOTE STIMULATION UNIT FUNCTIONAL BLOCK DIAGRAM



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Test commands from the GDIS are received as discrete levels in 8 bit groups with an identification line for each group. The groups are shifted into the input storage by a transfer pulse from the GDIS. Outputs from the storage drive a relay coil with each bit position. The relay contacts connect the desired vehicle test point to the correct stimuli generated in the conditioner, or a resistive load via a patch panel. The conditioner contains voltage dividers which convert the power supply outputs to the desired stimuli levels.

Stimuli verification during normal operation is provided by monitoring a separate contact set on each relay via the GDTS. In this manner, the test point stimuli configuration is known at all times.

Self test is performed by software in the CDS computer. A self test command sent from the CDS via the CDIS removes the signals from the stimuli relays. The CDS then checks all relays for pull-in and drop-out by issuing self test commands and verifying relay actuation via the relay monitor contacts. The stimuli power supply voltages are monitored constantly by the CDS via the CDIS to verify their correct operation.

<u>Interfaces</u> The Remote Stimulation Equipment interfaces with the GDIS for its inputs at all locations. The output interfaces for factory and ESF tests are the SC CB umbilical and the OSE umbilical. For pad tests, only the SC umbilical will be used for stimuli transfer to the CB.

4.4.8.3 Launch Control Center Equipment

- o <u>Identification and Usage</u> This equipment consists of a Launch Monitor Console that is used by the Capsule Bus Launch Coordinator during the countdown to monitor the condition of the Capsule Bus and test progress.
- o <u>Physical Characteristics</u> A two-bay sitdown type console with slanted control and display panels, intercom panel, writing surface, and under shelf panels containing a voice frequency tone receiver, dc power supply, ac power control, blowers and storage drawers as illustrated in Figure 4.4-7.
- o Operational Description The Launch Monitor Console is used during the launch countdown to display Capsule Bus subsystems status information required to determine Capsule Bus launch readiness. The operator also monitors displays that indicate the status of the CB STC, identifying the program, sequence or subroutine in progress. Hazard Alarm and Monitor System

LAUNCH MONITOR CONSOLE

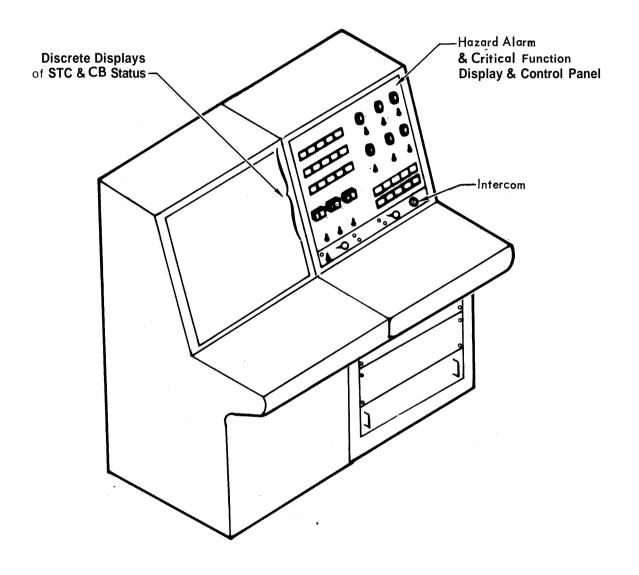


Figure 4.4-7

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functions are monitored and controlled as required when an emergency condition is encountered. Section 4.4.8.6 describes the Hazard Alarm and Monitor System in detail.

- o Performance Characteristics The basic function which is performed by the console is that of Capsule Bus and STC data display on a real time continuous basis. The data is received from the STC as voice frequency tones transmitted via standard 3 KHz phone lines. Frequency sensitive relays in the console convert the tone signals to bilevels that drive discrete displays. Selected status signals are sent to the Central Launch Coordinators Console. The console also receives critical parameter data in bilevel form via hardlines from the pad, which are fed to display drivers to activate panel indicators. Console panel controls send bilevel commands to the pad over hardlines that interface with the Hazard Alarm and Monitor System. Typical displays include pyrotechnic arm relay position, propellant tank pressures and critical CB temperatures. Typical controls include pyrotechnic arm relay reset, propellant dump control and dc ground power control.
- o <u>Interface Definition</u> The interfaces of the Launch Monitor Console are as follows:
 - 1. STC Test Conductor's Console Capsule and test status functions
 - 2. LCE Hazard Alarm and Monitor System Hazard alarm monitor and controls
 - 3. LCC Facility Power Facility ac power
 - 4. LCC Communications Intercom
 - 5. LCC Central Launch Coordinator's Console Selected Capsule Status functions.

Figure 4.4-8 is a functional block diagram of the Launch Monitor Console.

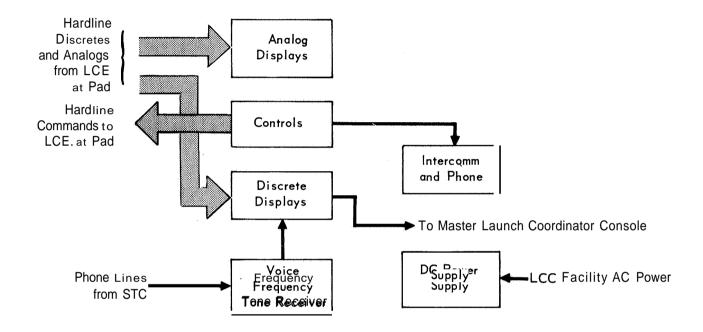
4.4.8.4 <u>LCE Required STC Equipment</u> - The System Test Complex (STC) equipment is used in conjunction with the LCE to perform essentially the same function as it does during CB system testing as described in paragraph 4.3.

The STC interfaces with the LCE in the following manner:

- o Via the Ground Data Transmission System to the ESF and Launch Pad.
- o By standard phone lines (audio tones) to the LCC.

A more detailed description of the LCE/STC interfaces is shown in the previous Figure 4.4-1.

LAUNCH MONITOR CONSOLE BLOCK DIAGRAM



4.4.8.5 <u>Hazard Alarm and Monitor System</u>

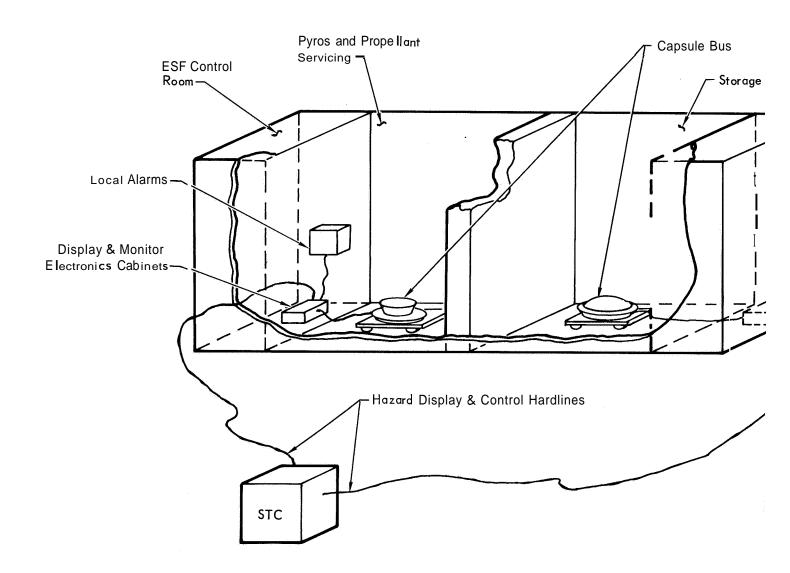
4.4.8.5.1 <u>Identification and Usage</u> - This system is used to monitor potentially hazardous systems and operations. It detects and warns by audible alarm and visual displays of impending dangerous or unsafe conditions at the launch pad, Explosive Safe Facility (ESF) and Capsule Bus (CB) storage area. The system provides both automatic and local controls to return the system or area to a safe condition in addition to automatically turning off Capsule Bus power and non-explosive proof facility power. A pictorial and block diagram is shown in Figure 4.4-9.

<u>Design Requirements and Constraints</u> The system is designed to meet the following requirements:

- o Monitor propellant and pressurant tank pressures and temperatures, pyrotechnic arming circuits, and pyrotechnic bus voltage
- o Monitor propellant concentration at the ESF propellant loading area and inside the canister following encapsulation
- o Display the preceding parameters locally at the launch pad, ESF and storage area and providing a local audible alarm when a hazardous condition exists
- o Provide CB pyro circuit switching and safety interlocks required for pyro testing
- o Automatically shut off CB power and non-explosion proof facility power when a hazard exists
- o Provide controls to return systems to a safe condition and accepting commands from the STC and LCC
- o Driving displays in the STC and LCC
- o Meet NEMA code requirements for explosion proofing
- o Provide back-up power to continue the preceding functions in the event of a facility power failure

Physical Characteristics - The system is self contained and automatic in the detection, alarm and safeing mode. Detectors, displays, alarms, back-up batteries and associated electronics are contained in 2 cabinets. Hazard alarm and monitor cabinets are located at the ESF, CB storage area and launch pad. Auxiliary detectors are provided at the ESF propellant loading area to monitor propellant concentration around loading equipment and the CB during propellant servicing. The system is interlocked with power at each location to shut-off non-explosion proof facility and CB power. Hardlines interconnect the cabinets at the ESF and storage

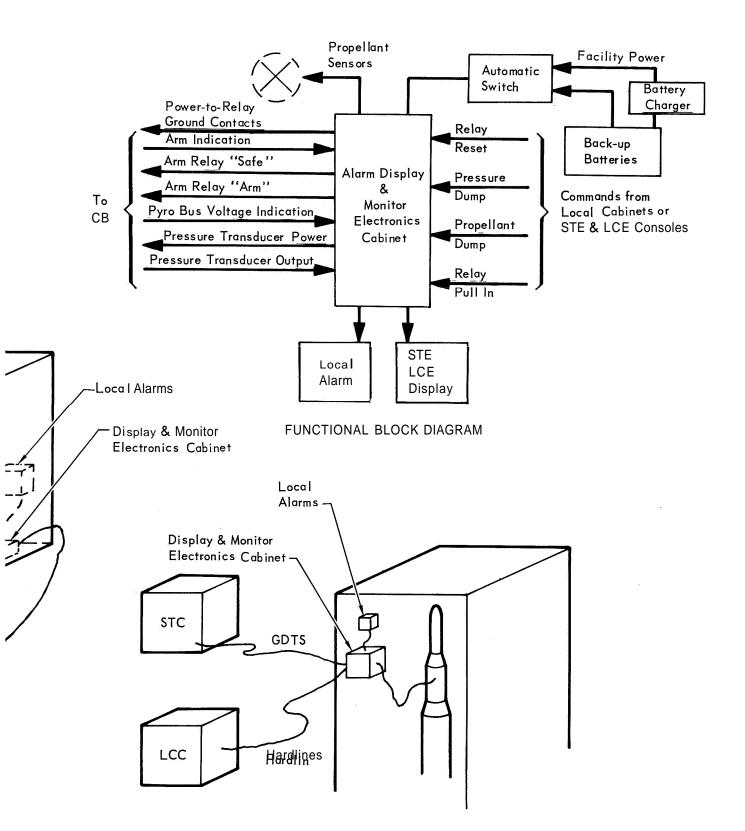
HAZARD ALARM & MONITOR SYSTEM



ESF HAZARD ALARM SUBSYSTEM

Figure 4.4-9

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LAUNCH PAD HAZARD ALARM SUBSYSTEM

area to the applicable consoles in the STC. At the launch pad, hardlines interconnect the cabinet to Hazard Alarm and Monitor Panel in the LCC and the GDIS connects the system to the STC. All electrical components are hermetically sealed or padded with GN₂ to meet NEMA code explosion proof requirements.

Operational Description - The system provides power for the Terminal Propulsion Subsystem (TPS) and Reaction Control Subsystem (RCS) propellant and pressurant tank transducers, propellant detectors and the OSE contacts of the pyrotechnic arming and pyro bus activating relays. Signals from the transducers, propellant detectors and arming relays are monitored along with pyrotechnic bus voltage, and propellant tank temperatures. These signals are automatically compared to preselected safe limit levels. If one of these levels is exceeded, facility and CB power is turned off automatically. Simultaneously the audible alarm is sounded and a display on the rack is lighted to indicate the location and nature of the hazard. Pyrotechnic relays are automatically activated to the safe position. Emergency dumping of the propulsion systems is initiated manually. The cabinet displays indicate propellant tank pressure, temperature and propellant concentration for each propellant detector. Ten detectors are used at the ESF propellant loading area to monitor the loading units, flight subsystem tankage and connections, and the propellant disposal system terminal boxes. At the launch pad, storage, and sterilization area, only the detector in the Canister pressurization Unit is monitored. In the event of a facility power failure the system automatically switches to its back-up battery power supply. This supply contains its own battery charger to maintain the batteries in a ready condition.

<u>Interface Definitions</u> - The system interfaces, with the following, as illustrated in Figure 4.4-9:

- o Facility power
- o Canister Pressurization Unit
- o ESF and Pad Propellant Disposal Systems
- o STE Propulsion Console and Sequential Console
- o LCC Hazard and Alarm Panel
- o Propulsion subsystem pressure and temperature transducers
- o Pyrotechnic bus and arming relays
- o Non-explosion proof facility power
- o Capsule Bus ground power
- o PV Hazard and Alarm System
- o Space Vehicle Hazard and Alarm System

4.4.8.6 UHF Receiving System

Equipment Identification - The UHF Receiving System consists of dual UHF receivers and RF monitoring equipment to perform measurements on the Capsule Bus UHF signals. The systems is ased at the CB contractor's factory and at KSC.

Design Requirements and Constraints - The UHF Receiving System is required to:

- a. Receive both 400 MHz Capsule Bus Radio Subsystem FSK modulated signals.
- b. Demodulate the FSK Subcarrier and provide a serial Pulse Code Modulated (PCM) bit stream to the System Test Complex (STC) telemetry processing equipment via the GDTS.
- c. Provide a means of measuring RF power and carrier frequency by remote control from the GDIS or by local manual control.
- d. Provide spectrum analysis of the Capsule Bus transmitted UHF signals.
- e. Provide remotely controllable power and switching for the UHF Receiving System.

<u>Physical Characteristics</u> - The UHF Receiving System is housed in a single standard cabinet, as shown in Figure 4.4-10.

<u>Functional Description</u> - The UHF Receiving System provides an RF interface with the Capsule Bus Radio Subsystem signals. RF monitoring and UHF receiving is controlled locally (manual) or by remote control from the Computer Data System. See functional block diagram Figure 4.4-10.

The RF signals are routed to an RF distribution panel where they are coupled to power meters, an electronic counter, a spectrum analyzer, and the UHF receivers. The receivers demodulate the FSK signal and provide two PCM inputs to the diversity combiner. The combiner output is a single serial pulse code modulated (PCM) bit stream which is sent to the STC for decommutation via the GDTS.

The GDIS interface control unit controls the position of the transfer switches to connect either of the UHF signals to the input of the frequency meter and selects the frequency range of the UHF receivers.

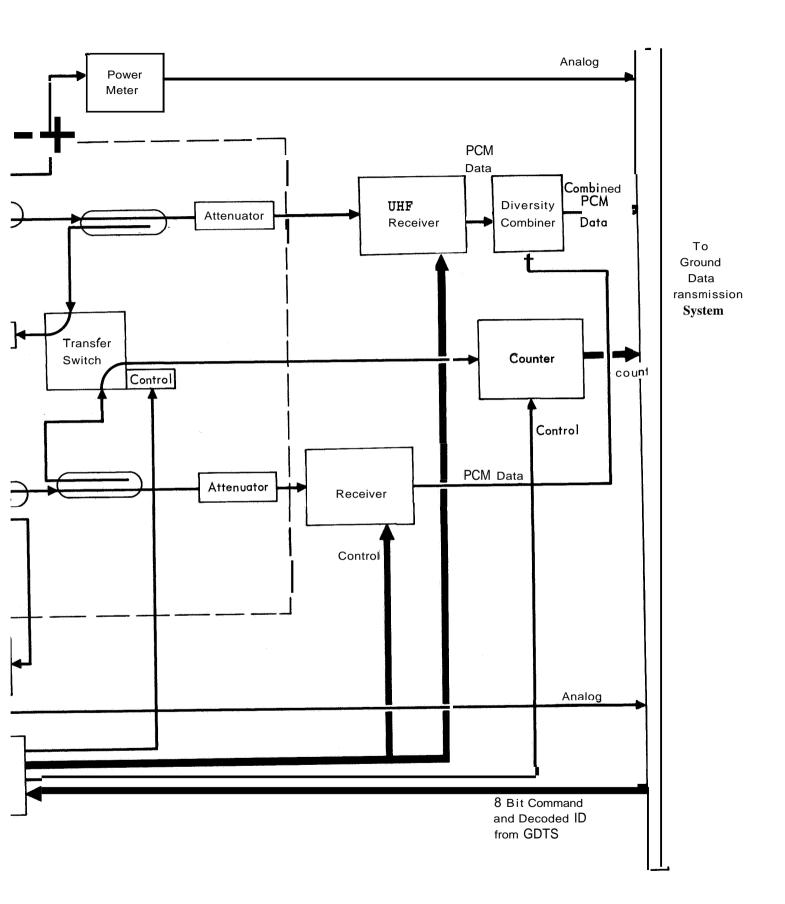
The spectrum analyzer permits the monitoring of the spectral characteristics of the Capsule Bus transmitted signals to verify that no spurious radiation is present.

Self-test is performed by switching a 400 MHz signal generator into the receivers, power meter and counter and monitoring the outputs locally or at the STC via the GDTS.

<u>Interfaces</u> - The UHF Receiving System interfaces with the GDIS and the CB Radio Subsystem as shown in Figure 4.4-10.

FUNCTIONAL BLOCK DIAGRAM UHF RECEIVING SYSTEM Spectrum Analyzer Receiver No. 1 Receiver No. 2 Spectrum Analyzer **RF** Distribution Panel Counter Diplexer PCM Simulator & UHF Signal Gen RF Distribution Panel UHF **Power Meters** Transfer Switch Load **GDTS Int Cont** Control Blower Loc Load Diversity UHF Diplexer J-BOX Transfer Switch From ESP via Control UHF Capsule Bus Transfer Switch Load Load Control Load PCM Power Simulator Meter UHF Signal Generator **GDTS** Interface Control Un **Directional Coupler**

Figure 4.4–10 4–68*←*/



4-68-2

- 4.5 CAPSULE BUS MZSSION DEPENDENT EQUIPMENT (MDE) Mission Dependent Equipment is required to supplement the capabilities of the Deep Space Network. This MDE will support Capsule Bus telecommunications in the areas of telemetry data acquisition, processing and display, and command generation and transmission. Special purpose procedures, routines and computer programs are also furnished as a part of MDE. This software is used in conjunction with the computers and data processing equipment at Deep Space Instrumentation Facilities (DSIF) stations and at the Space Flight Operations Facility (SFOF) for acquisition and processing of Capsule Bus data.
- 4.5.1 <u>Requirements and Constraints</u> The baseline design for Capsule Bus MDE is based on the assumption that the Flight Spacecraft contractor will provide the Capsule Bus contractor with the reconstructed, interleaved CB/ESP serial bit stream as received in the Spacecraft via the UHF link. The Flight Spacecraft MDE also provides the bit sync required for operation of the CB MDE.

The Capsule Bus MDE will provide hardware and software at DSIF sites and at the SFOF to meet the following set of requirements:

- a. Acquisition of interleaved, time-redundant CB/ESP data from the output of the Spacecraft MDE.
- b. Processing of the data to derive best quality data from the real-time, 50-second delay and 150-second delay data streams.
- C. Separation of CB data from the interleaved CB/ESP data.
- d. Transfer of data to the Telemetry and Command Processor (TCP) for processing.
- e. Formatting of this data for transmission to the SFOF over DSN communications links.
- f. Processing of this data in the Telemetry Processing Station (TPS) and Central Computer Complex (CCC) of the SFOF.
- g. Display of this data in formats suitable for use by engineering analysis teams.
- h. Furnishing a Capsule Bus Simulator to facilitate test and checkout of CB, MDE, and perform compatibility testing of CB MDE/DSIF interfaces.
- i. Implementation of CB command initiation, generation, transmission and verification, in conjunction with appropriate Spacecraft command MDE.
 Additional requirements include compatibility with:
 - a. Deep Space Network (DSN) equipment input/output characteristics.
 - b. DSN communications link capabilities.
 - c. DSN operational policies and procedures.
 - d. Engineering analysis team data requirements.

The major constraints considered in design on the MDE are:

- a. The method used to transmit CB data via the Spacecraft S-Band link to DSIF sites; i.e., multiplexing the interleaved CB/ESP data with Spacecraft data onto a subcarrier which modulates the S-Band carrier.
- b. The configuration and operating characteristics of the Spacecraft MDE at DSIF sites and at the SFOF.
- c. The format of CB data as obtained from the Spacecraft MDE, at DSIF sites and/or at the SFOF.
- d. The time-line availability and loading of the DSIF and SFOF Computer Complexes.
- e. The requirement for real-time or near real-time display of CB data at the SFOF.
- 4.5.2 <u>Equipment Identification List</u> The Capsule Bus hardware MDE is identified in terms of equipment at the DSIF sites and equipment at the SFOF. The related software for the DSIF and SFOF computers is discussed in Section 4.5.4.

4.5.2.1 DSIF Mission Dependent Equipment

- O Data Demultiplexing Equipment This equipment accepts the interleaved CB/ESP data from the output of the Spacecraft MDE, separates this data into three bit streams (real-time, 50-second delay, and 150-second delay), performs majority voting to derive best quality data, and buffers and formats this data for entry into the Telemetry and Command Processor (TCP).
- o <u>Command Interface Equipment</u> This equipment interfaces with the Spacecraft command MDE and enables CB command messages to be verified at the time of transmission.
- o <u>Capsule Bus Simulator</u> This equipment is used for compatibility testing and checkout of CB MDE at the DSIF sites and simulates interfaces between the Spacecraft and the Capsule Bus.

4.5.2.2 SEOF Mission Dependent Equipment

- o <u>Data Display Interface Equipment</u> This equipment accepts data from the Central Computer Complex (CCC) and the Telemetry Processing Station (TPS) in the SFOF, converts this data into formats suitable for driving displays, printers and recording devices, and enables distribution of data to engineering analysis teams for display.
- o Engineering Display Equipment Special-purpose displays and read-out equipment which present data in formats as required for use by engineering analysis teams.

- O Capsule Bus Control Console This console controls operation of the Data Display Interface Equipment, provides for alarm and status monitoring, enables call-up of selected data, and facilitates identification of critical data for further analysis and processing.
- o <u>Quick-Look Displays</u> These displays are on-line at the output of the TPS and provide for early Capsule Bus systems performance and status.
- Physical Characteristics The configuration of the MDE complies with JPL specifications for electronic equipment for use at DSIF sites and at the SFOF. Human engineering criteria and display techniques developed by JPL and other NASA activities, McDonnell-Douglas, and Philco-Ford, are utilized in the design of consoles and displays to facilitate their use by NASA and contractor personnel. Equipment characteristics such as size, shape factor, cabinet finishes, panel layouts, types of controls and connectors, and related items will follow accepted state-of-the-art design practices. Figures 4.5-1 and 4.5-2 show typical control console and display console configurations for use at DSIF sites and at the SFOF. Operational Description - Operational utilization of the CB MDE is described in terms of DSIF-located MDE, SFOF-located MDE, and communications links within the DSN. The functions and tasks to be performed by the MDE have been outlined in previous sections of this report. Operational sequences and data flow are now presented and methods for utilization of the MDE are shown. Figure 4.5-3 is a simplified block diagram of the major functional MDE elements in the DSIF and SFOF.
- 4.5.4.1 <u>DSIF Operational Utilization of MDE</u> Interleaved CB/ESP data and bit sync signals are obtained from the output of the Spacecraft MDE. These signals are processed by the CB Data Demultiplexing equipment and majority voting performed to derive the best quality data. This CB/ESP data is de-interleaved and the CB and ESP data separated. The CB data is buffered and formatted and read into the TCP, which performs decommutation, error detection and correction, and processes the data for entry into the station communications processor. This latter unit processes the data for transmission over the high speed data link (HSDL) to the SFOF. ESP data is sent to the ESP Contractor's equipment.

Capsule Bus commands are transferred from the SFOF to the DSIF within the Spacecraft command message structure. The CB command MDE interfaces with Spacecraft command MDE to validate CB commands as they are processed for transmission over the S-band uplink.

CAPSULE BUS MDE CONTROL CONSOLE

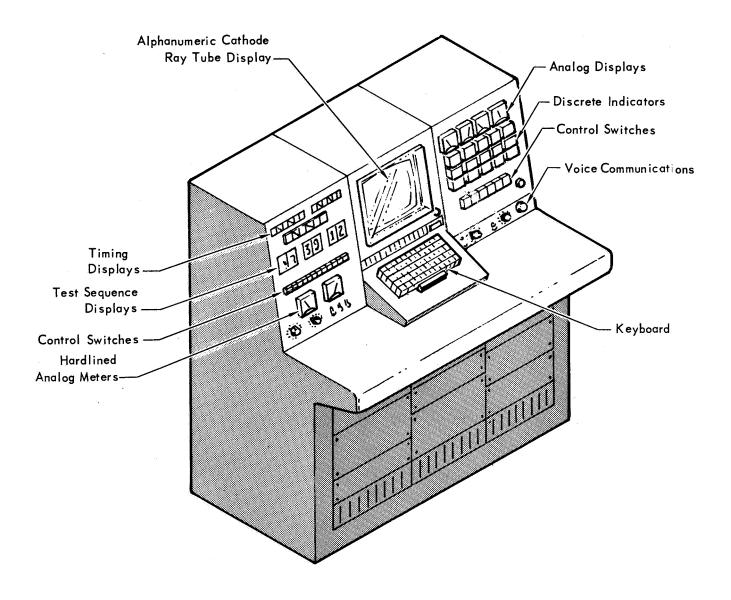
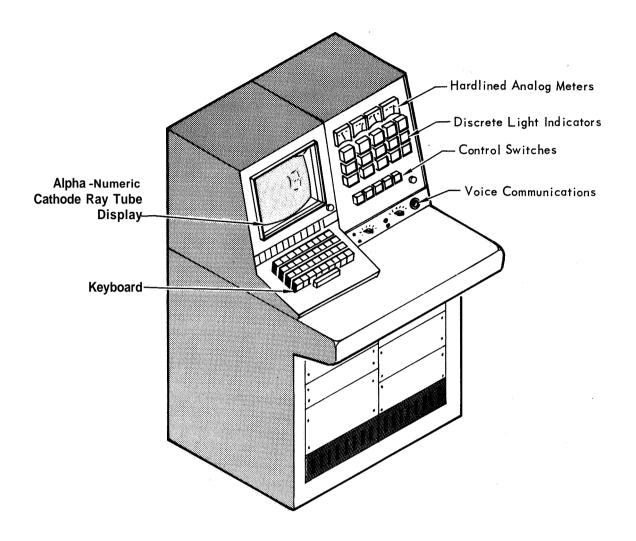
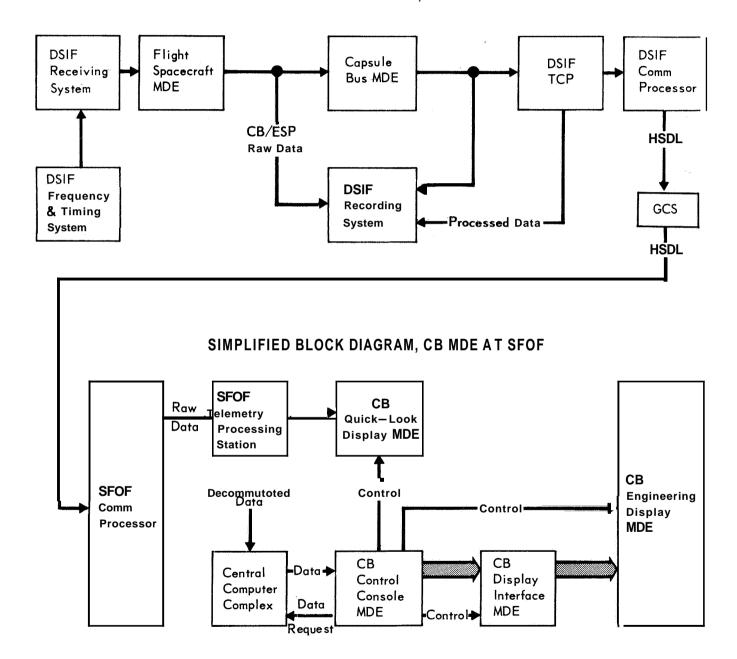


Figure **4.5–1**

TYPICAL CB MDE DISPLAY CONSOLE



SIMPLIFIED BLOCK DIAGRAM, CB MDE AT DSIF



HSDL = High Speed Data Link

GCS = Ground Communications System

4.5.4.2 SFOF Operational Utilization of MDE - Capsule Bus data received via the HSDL from DSIF stations enters the SFOF communications processor where address recognition and message validation is accomplished. The raw data from the communications processor is routed to the Telemetry Processing Station (TPS) for signal conditioning and decommutation. Decommutated data is fed to CB MDE quick-look displays for early identification of CB performance and status. This data is also fed into the 7288 data communication channel input of the Central Computer Complex (CCC). The CCC scans the data for alarm indication and initiates alarm messages to computer print-outs, monitors data for changes in data mode, performs calibration routines, verifies high and low check values of engineering coefficients, and formats the data for entry into the display and read-out devices.

The CB Control Console MDE provides a focal point for CB data collection and dissemination. The data is routed to appropriate displays, selected data is called up, and alarm and status functions are monitored. Other mission oriented data is also displayed at this console.

The data is routed via CB Display Interface MDE to the CB Engineering Display MDE for use by the CB engineering analysis teams. These displays enable presentation of engineering parameters and critical data, trend data, timesequenced events and related mission parameters.

- 4.5.4.3 <u>DSIF MDE Computer Software</u> The software considered in this report includes computer programs for use within the Telemetry and Command Processor (TCP) at the DSIF sites. Software development provides computer programs which contain the following characteristics:
 - o Performance in all operating modes with all permutations of input data consistent with capabilities of the TCP.
 - High probability of detecting submarginal performance or failure of CB subsystems.
 - o Minimal reprogramming of identical and/or similar functions to support the various levels and sequences of MDE operations.
 - o Flexibility of operation to support changes in data formats due to contingencies or alteration in mission sequences.

The software modular design will ensure compatibility with DSIF operational environment and computer program formats. Independent checkout of program modules and subprograms will provide structural and linkage compatibility with mission-independent programs. Additional requirements relate to the capability to checkout programs with simulated interfaces and in the actual operating environment.

The software enables the TCP to buffer, format, and edit the CB data stream as it is received from the MDE equipment. Each data frame is identified as it is stored in the input buffer. The data is then transferred to the communication processor for transmission over HSDL to the SFOF. The TCP software developed for CB data processing will be fully compliant with the current TCP computer configuration and with DSIF operating modes and data formats.

The concepts and criteria for software development outlined in Section 8.0 "Test Software" will provide guidelines for MDE software development.

Trade-offs regarding functions accomplished by equipment versus those performed by means of software for the DSIF and SFOF computers have been evaluated during the study. Programing costs and computer utilization effectiveness must be balanced against equipment costs, development time and reliability to allow the final decision regarding hardware versus software to be made during Phase C. 4.5.4.4 SFOF MDE Computer Software - Many of the same criteria considered for DSIF software also apply to the SFOF software. The additional utilization of the SFOF computers for mission control and operations, status monitoring and display control, and other non telemetry data handling imposes additional constraints on the software structure for the Capsule Bus.

Software is provided to enable the Telemetry Processing Station (TPS) to accept, process and format CB data from the HSDL. The TPS converts the data to an IBM-compatible, 36-bit digital format and produces bulk printer output for quick-look purposes. Data is time-tagged, frame synchronization is established, and this data fed to the PCM signal conditioner and PCM decommutator within the TPS. The data is then transferred to a PDP-7 computer for further processing into a format suitable for entry into the 7288 Data Communication Channel, which serves as the input/output buffer for the IBM 7044/7094 system within the Central Computer Complex (CCC). The CCC processes the data into formats suitable for driving both the on-line and off-line data display devices, performs analysis of the data, examines data for failure mode effects and trends, and derives quality assessments for each data channel.

Modular software is required for the PDP-7, 7044 and 7094 computers within the SFOF. This software enables the accomplishment of the functions described in the previous paragraph, and will be patterned after similar programs developed by JPL for use in other deep-space missions. The software will be fully compatible with JPL computer programming policies and will utilize the optimum machine language for each phase of the mission.

4.5.5 <u>Interface- Definition</u> Significant MDE hardware and software interfaces identified during the study are shown in Figure 4.5-3 and are grouped in the following way:

DSIF-MDE Interfaces

- a. Output of Spacecraft MDE and input to CB MDE.
- b. Output of CB MDE and input to the TCP.
- c. TCP software used for Spacecraft, SLS and ESP data processing and TCP software used for CB data processing.

SFOF MDE Interfaces

- a. Output of Telemetry Processing Station (TPS) and input to CB Display Interface Equipment.
- b. Output of TPS and input to CB Control Console.
- c. Output of Central Computer Complex (CCC) and input to CB Display Interface Equipment.
- d. Output of CCC and input to CB Control Console.
- e. TPS and CCC software used for Spacecraft, SLS and ESP data processing, and TPS and CCC software used for CB data processing.
- f. SFOF control consoles/displays and CB control consoles/displays.

Operational interfaces relate to priorities assigned to CB real-time data displayed at the SFOF versus Spacecraft, SLS and EP data. These interfaces are constrained by the loading on the DSIF TCP and the DSIF-SFOF communications channels; i.e., percentage of utilization of the TCP for processing of SLS, ESP and Spacecraft data.

Technical interfaces exist between data channels, sync channels, timing

lines, display drivers, control lines, and status monitors. Compatibility is required in areas of timing accuracy, sync jitter, noise immunity, signal isolation, data formats, and error detection and correction. In addition, the obvious requirements in terms of impedances, voltage levels, spurious signal rejection, and similar items will be met during the design phase of the program.

4.5.6 Reliability and Safety - Successful acquisition and processing of real-time data during crucial phases of the mission is directly dependent on certain elements of the MDE. For this reason, the operational reliability requirements imposed on the MDE are similar to those for the Flight Capsule equipment. Sufficient functional redundancy is provided to prevent total loss of data in the event of failure of an element of the MDE. Both pre-detection and post-detection recording of incoming data is performed to backup real-time data acquisition. In addition,

recording of processed data prior to transmission over the DSIF-SFOF communications links provides for a back up data source and use of an alternate communications link in event of failure of the primary link.

The design and implementation of MDE (including software) will prevent the existence of situations that are hazardous to personnel or potentially damaging to the equipment and facilities comprising the DSN, the Capsule Bus or any of its subsystems.

The full utilization is made of the time-redundant CB data to ensure a high level of confidence in reliability of the data. In addition, software design will be proven by detailed checkout routines accomplished on the TCP and CCC computers early in the program.

4.5.7 <u>Development Status</u> - No critical development problems are foreseen for the equipment located at the SFOF. Displays and consoles, similar to those developed for JPL, Langley Research Center and other NASA activities, present no significant new development effort.

The DSIF MDE development will proceed in parallel with that of the flight hardware. Where applicable and cost-effective, flight hardware circuits, components and techniques are utilized to provide operational compatibility and ensure high performance and reliability. An example of such an application to MDE is the DSIF Data Demultiplexing Equipment. The OSE Implementation Plan, Volume VI, Part D, describes the planning for development of System Test Complex Software and validation of test complexes at the DSIF and at the Capsule Bus Contractor's plant. The MDE software planning will be accomplished within the same framework, each development effort substantiating the results of the other. Growth Capability - The DSIF equipment and software design will recognize the possible expansion in data-gathering capability of the Flight Capsule systems. Trade-offs evaluated during the study in terms of processing data at DSIF versus at the SFOF indicate that sufficient growth potential is required in the MDE at DSIF sites to allow for partial unavailability of DSN communications links. Significant changes in Flight Capsule configuration, such as the deletion of the Entry Package, will be accommodated by minor alterations to the MDE equipment and reformatting of the subrautines in TCP software.

Software development will provide sufficient flexibility to effectively accommodate changes in data requirements and formats. Subroutines will be structured to allow for variations in data content and alteration in mission sequences without the necessity for generation of entirely new programs.

The SFOF equipment will permit addition of new control and display devices with a minimum of redesign or physical modification.

Extra input and output channels facilitate the inclusion of new sources of data into the information flow.

- 4.5.9 MDE Equipment Functional Descriptions The equipment chosen to implement the major Capsule Bus MDE functions outlined in Section 4.5.2 is described in the following sections. The equipment uses digital logic modules implemented by use of high-performance integrated circuits mounted on plug-in circuit cards for ease of access and simplified maintenance. Where feasible, equivalent circuits and components to those in the flight hardware are utilized in the interests of high performance, reliability and standardization.
- 4.5.9.1 <u>DSIF Data Demultiplexinn Equipment</u> A simplified block diagram of this equipment is shown in Figure 4.5-4.

Two signals are obtained from the Spacecraft MDE; interleaved CB and ESP PCM serial bit stream data at a rate of 2730 bps, and bit sync. These signals are applied via signal conditioning circuitry to a demultiplexer, whose operation is controlled by the bit sync signal. In the demultiplexer, successive bits are fed to the three output lines, i.e., bit 1 to Line A, bit 2 to line B, and bit 3 to line C. This places all real-time data on one line, 50-second delayed data on a second line, and 150-second delayed data on a third line. To identify which line contains real-time data, a three-channel time correlation process is accomplished as shown in Figure 4.5-4. When correlation is indicated at the output of one of the time comparators, the line having the 50-second delay contains real-time data and the other line contains 50-second delay data. The remaining line contains the 150-second delay data. The remaining line contains the 150-second delay data. The block diagram example assumes real-time data on line A.

The real-time data is applied via a 150-second delay unit to one input of a majority voter, the 50-second delay data is applied via a 100-second delay unit to a second input, and the 150-second delay data applied with zero delay to the third input of the majority voter. The output of this device represents an enhanced replica of the original, real-time interleaved CB/ESP data.

This data stream is now read into the de-interleaves, where the Capsule Bus data stream is separated from the Entry Science Package data stream. To accomplish this, the interleaved data is read into a storage shift register whose length is sufficient to include both the CP and ESP frame sync words, enabling the two data streams to be separated. These data, along with associated frame sync, are

DSIF CAPSULE BUS DATA DEMULTIPLEXING MDE

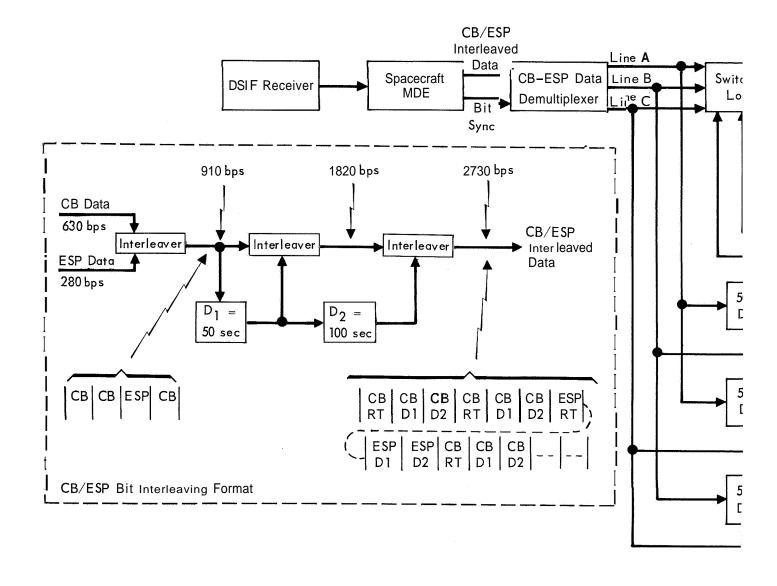
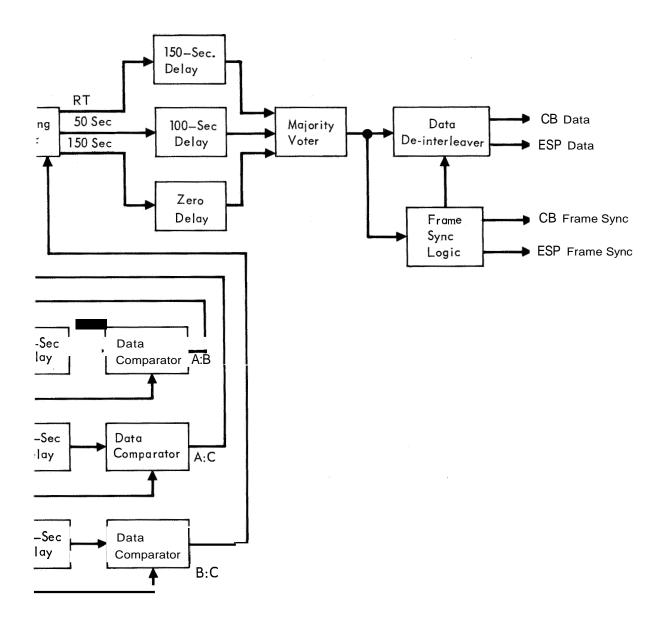


Figure 4.5-4 4-80-1



buffered and formatted for entry into the TCP, and processed for transmission via HSDL to SFOF.

4.5.9.2 <u>DSIF Command MDE</u> - This equipment interfaces with the Spacecraft Command MDE to validate Capsule Bus commands prior to final transmission. A simplified diagram of a method of implementation is shown in Figure 4.5-5, "DSIF Capsule Bus Command MDE." A detailed analytical treatment of the command system used in the SLS (and Spacecraft) is given in Volume III, Part C, Section 5.4.

Composition command instructions are received via the DSN communications links from the SFOF; correct receipt of these instructions are verified in the TCP by use of Spacecraft (S/C) MDE software. The TCP then issues command messages in the S/C format; some of these messages contain CB commands prefaced by a CB address. A S/C command baseband is generated, which phase-modulates the S-band up-link carrier. The DSIF monitor receiver acquires and demodulates this carrier, transferring the demodulated baseband to the S/C command detector and decoder MDE. The decoded command message at the S/C decoder output is compared with the original command message from the TCP by use of the S/C Command Verification MDE. If an error is detected, an inhibit signal is sent to the S/C Command Generation MDE to terminate the transmission.

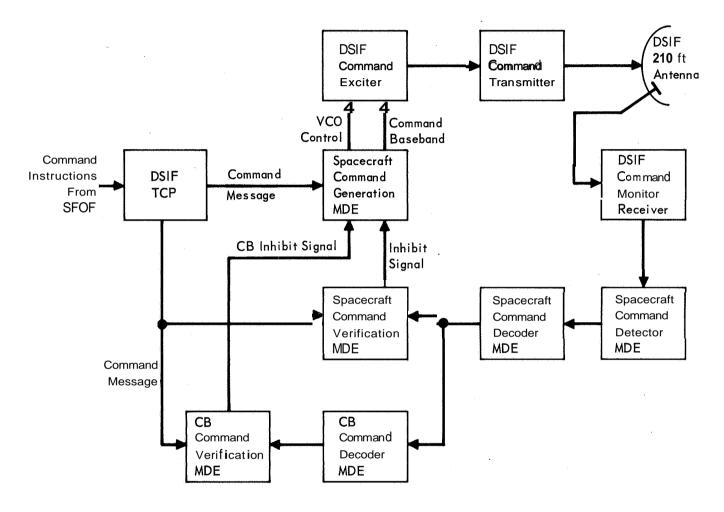
The CB Command Decoder MDE recognizes the CB address in the output of the S/C Command Decoder MDE, decodes the CB command message and transfers it to the CB Command Verification MDE. This unit compares the received CB command message with the CB command message from the TCP and sends an inhibit signal to the S/C Command Generation MDE if an error is detected.

The CB command MDE function may be accomplished entirely within the Spacecraft command MDE, as determined by additional studies by both Spacecraft and Capsule Bus Contractors.

4.5.9.3 SFOF Data Display Equipment - This equipment consists of multi-function displays meeting the requirements of the Capsule Bus subsystem engineering analysis teams and designed to make maximum use of the data received via the CB telemetry link. Display configuration is fully compliant with JPL specifications regarding cabinet physical characteristics, human engineering criteria, display formats, and control and monitor functions.

Systems evolution will allow a more detailed development of engineering display requirements during Phase C. However, representative displays are described to outline the categories of equipment which have been considered.

DSIF CAPSULE BUS COMMAND MDE



Cathode ray oscilloscope displays which present english language, alphanumeric lines of computer print-out data on either an automatic or a call-up basis
are provided in each of the engineering analysis team areas. By means of adaptive
programming, other data to be displayed includes actual versus estimated values of
selected parameters, status, performance indicators, mission alerts-, data nomenclature and engineering values. A control panel allows changes in display
operation to be manually controlled; certain display functions can be recalled or
inhibited.

The x-Y plotters can either be driven from the computers in an automatic mode or from off-line data sources. The pen recorders display related subsystem parameters to provide a time-history record of subsystem performance and occurrence of critical or significant events. The X-Y plotters enable graphic display of trend data to indicate potential degradation in system performance. Alpha-numeric annotation of plotted data as it is displayed allows for maximum visibility of important information.

4.5.9.4 <u>SFOF Display Interface Equipment</u> - This equipment accepts the output data from the Central Computer Complex and the Telemetry Processing Station and buffers and converts it into appropriate formats for distribution to the SFOF MDE display equipment. The following functions are provided:

- o Signal conditioning and level-changing
- o Parallel-to-serial conversion
- o Data combining and interleaving
- o Data switching and distribution
- o Isolation and line driving
- o Digital-to-analog conversion

In conjunction with the SFOF Capsule Bus Control Console, this equipment provides a focal point for collection, control and distribution of CB data at the SFOF. Plug-in modules and circuit cards allow easy accommodation to changes in data dissemination and display requirements. Solid-state switches provide for speed, reliability and flexibility of control.

4.5.9.5 SFOF Capsule Bus Control Console - Management of CB engineering data within the SFOF is implemented by use of a CB Control Console. It provides for control of the Display Interface Equipment described in Section 4.5.9.4 above, and allows the CB System Manager to have immediate access to critical segments of CB data.

An oscilloscope display, similar to that described in Section 4.5.9.3 above,

enables CB data to be displayed simultaneously with other mission oriented data to enhance visibility into mission operations. Status and alarm monitors, critical time and event indicators, and CB system performance level read-outs are included to facilitate the making of decisions.

4.5.9.6 <u>DSIF Capsule Bus Simulator</u> - The MDE used for simulation of the Capsule Bus Telecommunications System will be combined with that used for the Entry Science Package to facilitate control and interleaving of the data.

Figure 4.5-6 shows the major elements of the simulator. The RM data generator generates several words of CB PCM data at bit rates of 7, 273, 630, 280, 910 and 2730 bps to simulate the several data modes of interleaved CB and ESP data. Data, frame sync, and bit sync are delivered to the data combiner, where tape playback data is also received. The tape playback unit enables recorded test data obtained during CB system and subsystem tests to be processed through the DSIF MDE and TCP, and comparisons of input and output data made. Generated or playback data can be routed through the data delay unit, and 50-second or 150second delays imposed on the data, which is fed back into the data combiner. mode control enables selection of generator bit rate, tape playback operation, selection of real-time or playback data, and selection of real-time, 50-second delay and 150-second delay data. It also enables bits to be dropped in a data sequence, interchanging of real-time and delayed data to test decommutation, synchronization, momentary removal of frame sync or bit sync, and setting of output levels. The signal conditioning amplifier provides isolation between data combiner outputs and the lines used to transfer data to the MDE, and enables the levels of these lines to be set.

Digital logic cards are used for mounting of the integrated circuits used to implement these functions. Standard controls, switches and connectors are used to provide compatibility with other JPL equipment.

DSIF CAPSULE BUS SIMULATOR

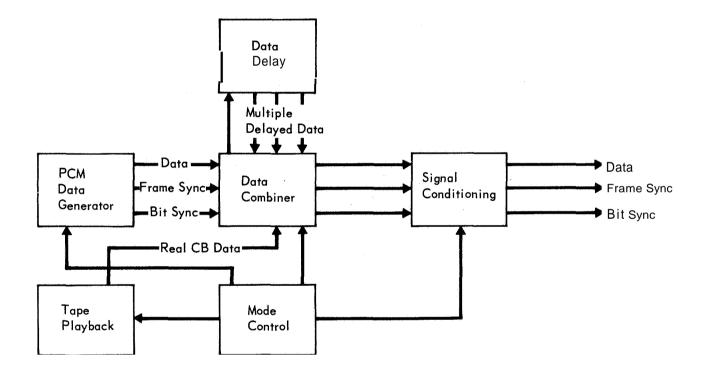


Figure **4.5–6**

SECTION 5

CAPSULE BUS SUBSYSTEM-LEVEL TEST EQUIPMENT

Subsystem Test Equipment (SSTE) described in this section provides complete test capability for design and operational verification of individual flight subsystems which compose the Capsule Bus. Direct access to the subsystem or its elements through the flight and OSE connectors permits this portion of the SSTE, identified as Subsystem Test Sets (SSTS), to be used in the performance of detail-level subsystem tests and fault isolation to a replaceable subassembly. Descriptions of the test sets are based on the test functions and requirements of the Capsule Bus subsystems only, i.e., independent of Surface Laboratory or Entry Science Package subsystems test requirements. (An alternate approach, described in detail in Section 10.6, combines the test requirements of ESP subsystems with those of the Capsule Bus or Surface Laboratory to effect a reduction in the total quantity of test equipment required for subsystem-level tests.)

5.1 SUMMARY - Capsule Bus Subsystem Test Sets provide the capability to accurately, thoroughly and expeditiously verify proper operational performance and to fault isolate the flight subsystem in the event of a malfunction. Each flight subsystem, or functional group of subsystems, is supported by its own test set to assure minimum schedule interference and OSE complexity.

Selected Capsule Bus subsystem test sets which are automated for test sequence control, data gathering and evaluation are the Guidance and Control, Radar, Sequencer, and Telecommunications Subsystem Test Sets. Analysis of the number and type of tests, test mechanization complexity and test time for these subsystems indicate that test automation is an efficient, cost-effective approach.

Specific functions provided by the SSTS are:

- a. Control, stimulate, power and measure responses of the flight subsystem or any of its elements in real time, repeatably, for performance verification.
- b. Identify and record all test data for off-line analyses for those test sets which are automated; data gathering is performed by the operator for the test sets not automated.
- c. Provide subsystem fault isolation ability to the replaceable subassembly level.

d. Provide self-test and calibration capability to validate the OSE prior to or during tests, automatically as a subroutine or manually by test procedure.

A resume of subsystem test set performance characteristics of our selected concept follows in paragraph 5.2; the remaining paragraphs of this section provide detailed descriptions of each test set.

- 5.2 GENERAL Performance and design features which are common to each of the subsystem test sets are discussed in the paragraphs which follow.
- 5.2.1 <u>Equipment Identification and Usage</u> Test equipment comprising the Capsule Bus Subsystem Test Sets are functionally grouped for independent and/or simultaneous subsystem tests as follows:

Electrical Power Electrical Power

Guidance and Control Guidance and Control

Propulsion Reaction Control, Terminal

Pyrotechnic Pyrotechnic

Radar Landing Radar, Radar Altimeter

Sequencer Sequencer

Telecommunications Antenna, Command, Data Storage,

Radio, Telemetry

Thermal Control Thermal Control

An equipment functional check is performed on each subsystem and its elements, using the subsystem test sets, prior to flight hardware installation into the Capsule Bus. Proper subsystem operation is thus verified prior to subsystems integration and continuity of test data is maintained.

As subsystems are integrated into the capsule, the SSTS's are used to establish subsystems operational compatibility. During the latter part of major module integration, the subsystem test sets are used simultaneously with STC equipment to provide a correlation between integrated subsystems test data and system performance. This correlated data is important for decision-making in the event of anomalies during critical test phases at KSC or mission operations. When the Capsule Bus is mated with the Canister and Adapter during integration direct accessibility by the subsystem test equipment to the flight hardware is restricted, terminating detailed subsystem-level tests. However, SSTS's may be used during environmental tests of the Capsule Bus for anomaly evaluations.

One complement of CB subsystem test sets will be required at KSC during

pre-launch and launch test phases for contingencies.

In addition to the preceding utilization, it is anticipated that subsystem test sets may be used to perform pre-delivery acceptance (PDA) tests (design verification) prior to shipping the flight subsystem from major subsystem vendors. Several benefits result from this SSTS utilization which contribute directly to mission success, namely; elimination of test variables between the vendor and CB contractor's facilities, a reduction in test time and costs at the vendor's facility, assurance of operable OSE hardware and software prior to receipt of the equipment at the CB contractor's plant.

5.2.2 <u>Design Requirements and Constraints</u> - Design of the Capsule Bus Subsystem

Test Sets is in accordance with JPL and flight-hardware-derived requirements as discussed in Section 2, Part D.

An operational constraint is levied on use of the subsystem test sets by the mating of the Capsule Bus and the Adapter and Canister. Capsule Bus, Surface Laboratory, and Entry Science Package test data, following mating, are derived from the telemetry down-link and by OSE umbilical test parameters available to the subsystem consoles in the Systems Test Complex.

The subsystem-level test equipment is designed to comply with class 100,000 clean room requirements. One complete set of SSTS is installed in the clean room for use during equipment functional tests and initial subsystem integration tests. Interfacing the flight subsystem elements with its associated test equipment by short hardlines, preserves the quality of the test data and permits the test operator ready access to the unit under test, and test controls and readout.

Several modules or panels within the test sets are of common design to reduce engineering costs, maximize total supportability of the test equipment and minimize operator indoctrination for the support equipment program. Out-of-tolerance monitoring and alarm circuitry, power and protection circuitry, analog and digital display panels, and analog-to-digital converters are standardized in design and hardware to the extent practical in each test set. Integrated circuitry is used extensively in the test set design, with discrete components incorporated as required, for reliability, accuracy and physical compactness.

5.2.3 <u>Physical Characteristics</u> - Subsystem Test Sets are contained in standard electronic equipment cabinets with special cabinets for the automatic processor when included. Casters are provided to facilitate mobility. Power and environmental conditioning for the flight subsystem under test are provided by the test set during subsystem or lower level testing.

Interconnections between cabinets and flight equipment are made by terminal boards and connectors accessible from the top or bottom of the test set. Connectors and cables are designed to minimize hookup time; connector keying and color coding are used throughout the OSE to prevent erroneous connections.

The SSTS installation for EFC and module buildup is shown in Figure 5.2-1. The equipment is functionally grouped to optimize the electrical, physical, functional and man-machine interfaces required during subsystems tests.

5.2.4 Operational Description - A functional block diagram of a typical SSTS is shown in Figure 5.2-2. The test set consists of three functional sections; an automatic processor, an interface unit and the basic test equipment. The test sets which are not automated consist of only the basic test equipment. An interface may be added to the manual test sets if required; however, analysis of the subsystem test functions of the manual sets indicate that test automation is not cost-effective and therefore the interface has not been incorporated in the manual test sets.

The automatic processor provides test sequence control by the test program stored within its memory; the program may be modified by the teletype keyboard or the punched-tape reader. In addition to control, the processor monitors and compares subsystem responses to stored limits, outputs out-of-tolerance data to the teletypewriter, outputs all test data, time-tagged to the paper tape punch for recording, and provides OSE self-test and fault isolation capability.

The interface unit processes the command data from the processor and controls the basic SSTS equipment. Response data is multiplexed and conditioned for use by the processor.

Equipment comprising the basic test equipment consists of signal generators, displays, clock, loads, protective circuitry, oscillographic recorders and alarm monitoring circuitry. Items of test equipment are selected for multiple function capability, reliability, and availability, in order to reduce OSE operating and maintenance costs.

- 5.2.5 <u>Performance Characteristics</u> Significant SSTS performance characteristics common to all of the test sets are summarized herein.
 - a. Measurement Accuracy: Accuracy of the SSTS measurement devices is in general an order of magnitude greater than that of the parameter measured.
 - b. Test Repeatability: Repeatability of tests is maximized by automation, fixed interconnections (by the use of matrix boards) and by

SSTS INSTALLATION AT CAPSULE BUS INTEGRATION SITE

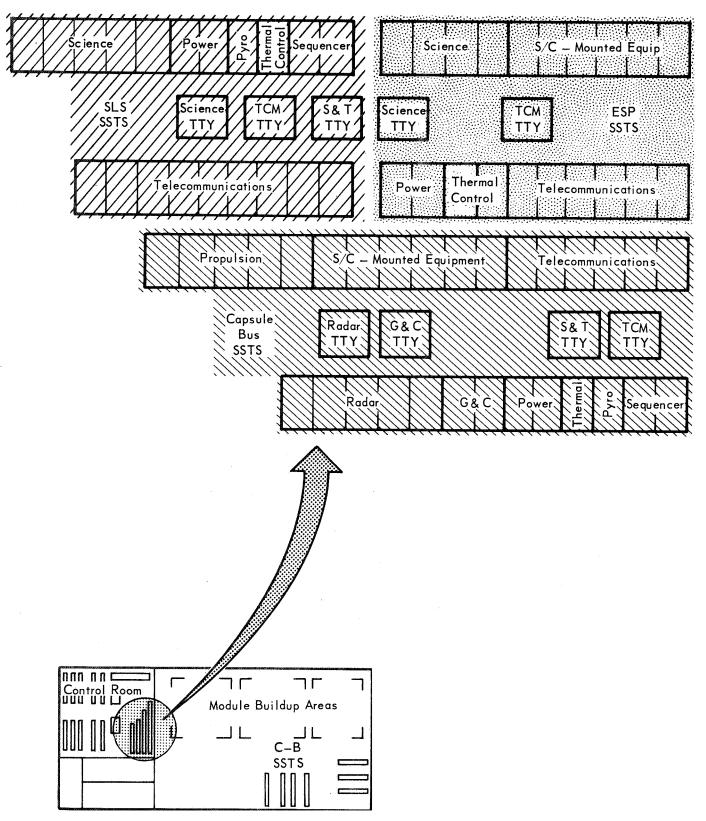


Figure **5.2–1**

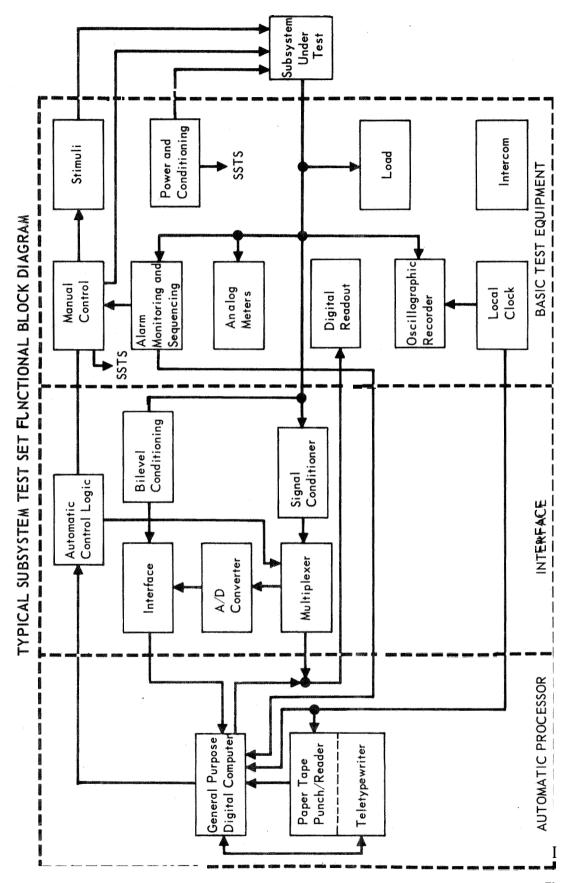


Figure 5.2-2

- incorporation of digital techniques for measurement when possible.
- C. Test Time: Time required for tests is minimized by automation where effective. Minimum test time reduces flight hardware operating time.
- d. Marginal Testing: Stimuli are varied in time, amplitude, pulse width or frequency (according to the selected parameter) to determine marginal operating performance. Resulting test data are especially useful to launch commitment decision-making.
- e. Protective Circuits: Protective devices and circuits are incorporated to assure improper or harmful signals are not applied to flight hardware or OSE.
- f. Out-of-tolerance Parameter Indications: Should a parameter being monitored appear outside the tolerances established in the test program or procedure, a warning light on the test set control panel illuminates and the parameter and its value is printed out on the teletypewriter in the automatic control mode. Critical or destructive parameters are monitored and an out-of-tolerance condition causes hard-wired protective circuitry in the test set to drive the test set and unit under test to a safe condition. If the out-of-tolerance condition is not of a critical nature, the automatic test routine permits the operator to clear the malfunction and/or continue the test.
- g. Self-Test: An OSE self-check is incorporated at the beginning of a test sequence and at any point in the sequence when the functional setup is considerably changed. In addition, when a malfunction is detected by the test set, a self-test is prescribed automatically or manually as applicable to the test set.
- 5.2.6 <u>Interfaces</u> Specific interfaces are listed with the description of each SSTS. The SSTS are capable of interfacing with a general purpose digital computer for test sequencing and monitoring with the exception of those noted previously where automation is not a cost-effective approach. However, a computer interface may be added, if desired, to these test sets.
- 5.3 ELECTRICAL POWER SUBSYSTEM TEST SET
- 5.3.1 <u>Identification and Usape</u> The Electrical Power Subsystem Test Set provides the capability to perform all pre-delivery acceptance (PDA) tests, equipment functional checks (EFC) and subsystem tests of the Electrical Power subsystem and supplies electrical power to the Capsule Bus if the Electrical Power subsystem or any of its elements are not installed or operating.

- 5.3.2 <u>Physical Characteristics</u> The Subsystem Test Set (SSTS) is packaged in two standard electronic equipment cabinets on castered bases. Cabinet configuration is shown in Figure 5.3-1.
- 5.3.3 Operational Description Because of the fundamental nature of the tests, the simplicity of the measurements involved and the relatively small number of operations performed, the SSTS is manually operated. Critical parameters are monitored continuously and visual and audio alarms are provided by hardwired logic to indicate out-of-tolerance conditions.

Self-testing is accomplished by simulating the subsystem parameters which are measured or controlled, and by checking the response of all monitors and alarms to both marginal and nominal conditions; and by verifying the stimuli applied to the flight subsystem by measurement with standard test equipment.

5.3.4 <u>Performance Characteristics</u> - The SSTS block diagram shown in Figure 5.3-2 is designed to perform the functions tabulated in Figure 5.3-3 and those discussed below.

Controlled dummy loads are provided to simulate normal CB electrical loads and to provide selected battery discharge rates. A constant voltage power supply having a range of 20 - 40V provides simulated battery power to the Electrical Power Subsystem in the CB. A constant current power supply is provided for battery charging purposes. Current limiting, voltage limiting, and external voltage sensing devices are incorporated in the SSTS design both for regulation and circuit protection.

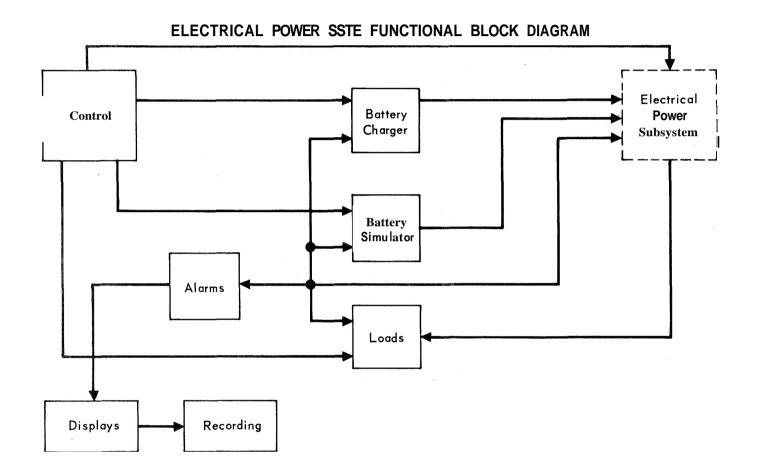
Meters and recorders are provided to measure and monitor all power subsystem analog parameters such as battery voltage, charge and discharge current, and net ampere-hour charge and discharge.

The switching points of the DC bus voltage sensors are checked by varying the cruise power and backup power bus levels and determining when the sensor switches to the alternate power source. Switchover point of the CB charger, from full charge to float charge, is checked by monitoring charger output current versus battery voltage, to verify proper operation of the charger. The output of the battery charger is tested for voltage and current by standard test equipment. Known currents are passed through the subsystem current shunts and the telemetry outputs to provide a calibration of the telemetry power level sensor.

5.3.5 <u>Interfaces</u> - Interfaces are shown in Figure 5.3-4. The single-point ground concept used by the Capsule Bus Electrical Power Subsystem is maintained by the Interface and the test set.

ELECTRICAL POWER SSTS

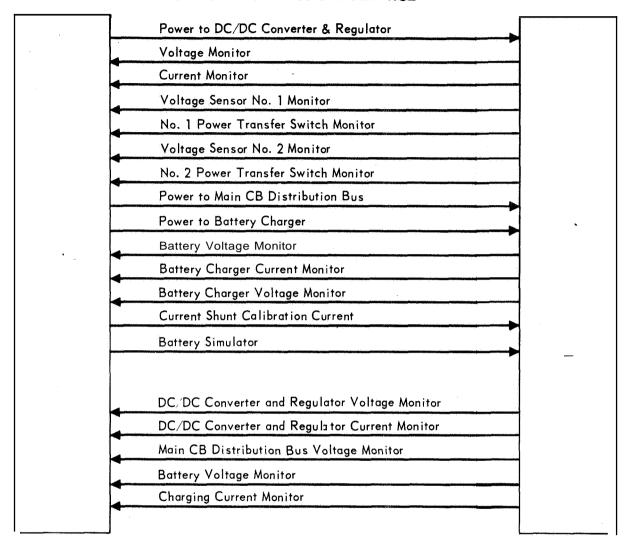
	Loads	Volt Meters Ammeters Amp - Hour
	· · · · · · · · · · · · · · · · · · ·	Meters
	Alarm Panel	Displays
	Constant Current Power Supply (Battery Charger)	Controls
		Writing Surface
	Constant Voltage Power Supply (Battery Simulator)	Analog Recorders
		Rack Power Supply
	Blower	Blower



ELECTRICAL SUBSYSTEM TEST REQUIREMENTS

Measuring Device	Range and Accuracy	Parameter	
Analog Voltmeter	15 - 40 <u>+</u> 0.1V	Bus Voltage Monitor	
Digital Vo I tmeter	o - 100 <u>+</u> 0.1mv	Current Monitor All Telemetry Signals	
*	0 - 40 ± 0.01V	Voltage Sensor #1 Voltage Sensor #2 Battery Voltage Monitor	
Ammeter	0 - 50 <u>+</u> 0.05 AMP	Battery Charger Current Bus Current Monitor	
	0 - 10 <u>+</u> 0.01 AMP	Shunt Calibration Current	
Ampere-Hour Meter	999 ± 0.1 AMP-HR	Battery Net Charge or Discharge	
Visual Indicators	State 1 or State 2	Power Switching and Log Relay Positions	

ELECTRICAL POWER SSTS INTERFACE



- 5,4 SEOUENCER SUBSYSTEM TEST SET
- 5.4.1 Equipment Identification and Usage The Subsystem Test Set (SSTS) for the Sequencer Subsystem provides all the equipment necessary to perform equipment functional checks (EFC) and installed subsystem tests at the Capsule Bus (CB) contractor's plant; in addition it may be used to perform pre-delivery acceptance (PDA) tests at the subsystem vendor's plant. The test set is also used during subsystems integration tests to provide direct subsystem control and monitoring via the OSE connectors.
- 5.4.2 <u>Design Requirements</u> The Sequencer SSTS is required to perform a complete diagnostic analysis and malfunction isolation for the Sequencer and Timer (S&T) and the Test Programmer (TP). Specifically, the following functions are required of the SSTS:
 - a. Supply power.
 - b. Simulate command link data, sensor inputs and In-Flight Test Programmer inputs.
 - c. Monitor reference frequencies.
 - d. Monitor and supply clock pulses, input signals and loads for telemetry data.
 - e. Monitor and supply loads for discrete outputs.
 - f. Monitor and supply clock pulses, input signals, and loads for guidance and control data.
 - g. Monitor and supply stimuli for diagnostic data.
- 5.4.3 Physical Characteristics The Sequencer SSTS is packaged in two standard electronic equipment cabinets and an automatic processor cabinet as shown in Figure 5.4-1. It is mounted on a castered base and is designed to be easily disconnected and connected into the test complex cabling, facilitating mobility. The test set incorporates standard modules which are of common design for major subsystem test set usage, such as the automatic processor, malfunction alarm unit, etc. The construction provides for growth, safety interlocks, fault isolation test points, and plug-in components to, implement human engineering factors and maintainability concepts.
- 5.4.4 Operational Description The test set (SSTS) block diagram is shown in Figure 5.4-2 and identifies the major functioning elements comprising the test set which are described briefly as follows:
 - a. Automatic Processor Unit: Provides for automatic test sequence control and instrumentation setup, data GO/NO GO comparisons and OSE self-check

SEQUENCER SUBSYSTEM TEST SET

A				
	Analog Response Unit		Malfunction Alarm Unit	
	Master Clock Digital Logic Unit Data Distribution Unit		Bilevel Stimuli Unit	
			Bilevel Response Unit	
			Displays	
	S&T Adapter	TP Adapter	Master Control Unit	THE RESERVED AND ADDRESS OF THE PARTY OF THE
	Writing		Surface	
	Analog/Event Chart Recorder		Processor Interface Unit	Automatic Processor Unit
	Chart	CCOIGE	DC Power Supplies	Time Code Generator
	Blower		Blower	Blower

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SEQUENCER SSTS BLOCK DIAGRAM

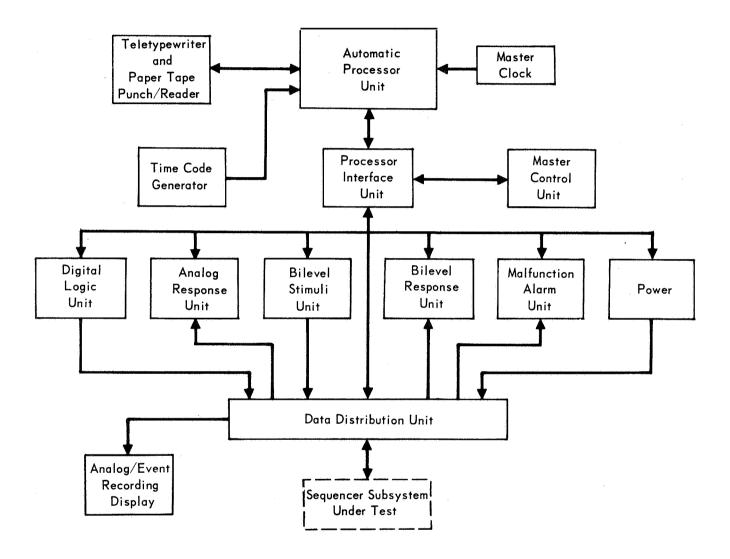


Figure **5.4–2**

- routines. The teletypewriter and paper tape punch/reader are used for automatic processor input/output.
- b. Digital Logic Unit: Provides for generating and receiving digital data associated with the sequencer and timer and test programmer, logic for time and frequency measurements and data storage for subsequent processing.
- c. Analog Response Unit: Provides an analog multiplexer, analog to digital converter and signal conditioning for measurement of analog parameters. The multiplexer is of the "on demand" type to implement high sampling rates of defective or out-of-tolerance parameters.
- d. Bilevel Stimuli Unit: Provides programmable bilevel sources for discrete commands.
- e. Bilevel Response Unit: Provides bilevel sensors for monitoring discrete parameters.
- f. Master Clock: Provides an accurate time base for measuring frequency and time.
- g. Malfunction Alarm Unit: Provides analog and bilevel, settable hi/lo detectors for continuous monitoring of key/critical parameters. Visual/ audible alarms are used for indication of key parameter status with an automatic shut down routine for critical conditions.
- h. Analog/event recorders/displays: Provides for selective recording/display of analog/bilevel parameters for time-line plots.
- i. Power: Provides a programmable power supply for performance margin subsystem tests.
- j. Time Code Generator: Provides for time tagging recorded/printed data in real time.
- k. Processor Interface Unit: Provides for data input/output to the automatic processor.
- 1. Data Distribution Unit: Provides flexibility in signal routing between the subsystem under test and the test set modules.
- m. Master Control Unit: Provides manual controls and displays for operating the test set in its automatic and manual modes and includes thumbwheel switches for setting in subsystem component serial numbers and other test information for the data bank,

Additional descriptions of standardized modules used in the subsystem test sets are described in Section 5.2.

The reference frequencies (1 KHz and 38.4 KHz) are measured to five significant figures by digital modules contained in the digital logic unit. The start/stop gate time is provided by the master clock.

The measurement of time associated with each of the 80 output discretes is also determined through the use of logic modules contained in the digital logic unit. The test set provides a start command to the S&T and to the master clock count down register as a t $_{o}$ reference. The S&T will then scan its 128 words (16 bits/word) in memory and decrement the words associated with the discrete outputs to zero thus providing the required time delays.

The test set monitors these outputs in parallel to determine that each output has occurred at the proper time and that the others have not occurred. A circuit configuration is devised that scans all of the 80 outputs in a time less than the smallest increment of S&T time i.e., less than 50 milliseconds. When a change in state is sensed, (as all of the 80 lines are scanned) flip-flops are set that enables master clock time (or measured time from to to the event) to be transferred to the automatic processor memory for validation. The flip-flops also provide memory for the discrete output pulses for identification of the output number associated with the recorded time. The master clock's least significant bit is 10 milliseconds, the scan rate is 10 K samples per second and the processor memory cycly time is 8 microseconds all of which will enable the various combinations of discrete output time measurements to be made almost simultanously.

The S&T digital interfaces, i.e. G&C, telemetry and command link, are tested by supplying 10 KHz clock pulses and either supplying or monitoring the bi-level data request/data ready signals and serial data transfer either to or from the S&T through use of the processor interface unit.

The S&T provides a ground test mode that permits testing in a shorter time than the (2^{16} seconds maximum flight mode. This is accomplished in the S&T through bypassing of some of the clock count down registers and is enabled by a discrete command from the test set via the OSE test connectors.

The S&T input command words are 32 bits in length and are composed of address and data bits. The test set processor interface unit in conjunction with the automatic processor will generate these words for simulating the command link inputs to the S&T. A discrete command to the S&T provides for memory dump via the telemetry output for memory readout, These words are received by the test set processor interface unit and transferred to the processor memory for subsequent

validation. The input/output word data rate is a functional of the clock signal supplied to the S&T and is approximately 10 KHz. The S&T solid state output drivers are tested for back-leakage (turn off) and saturation (turn off) resistance.

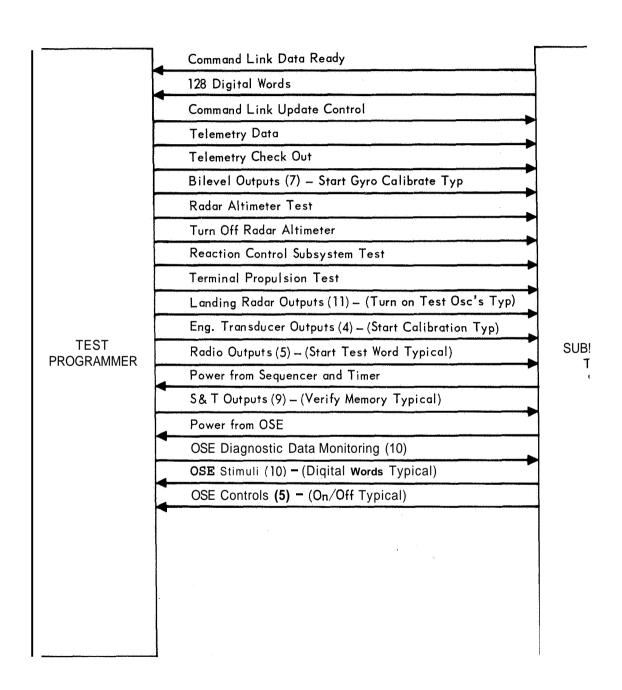
Tests of the inflight checkout programmer are similiar to those for the sequencer. The digital words to be loaded into the TP memory unit and the readout of these words are supplied and monitored by the test set. The discrete output commands are also time measured by the test set, but have greater time tolerances associated with these events.

- 5.4.5 <u>Interfaces</u> Subsystem interface information is shown in Figure 5.4-3. Individual subassemblies may be interfaced with the SSTS by connecting the subassemblies directly to the test adapter units which are a part of the Test Set.
- 5.5 GUIDANCE & CONTROL SUBSYSTEM TEST SET (SSTS)
- 5.5.1 Equipment Identification and Usage The G&C Subsystem Test Set is used for equipment functional checks (EFC) at the capsule bus contractor's facility prior to G&C subsystem installation into the Capsule Bus and to provide direct subsystem control and monitoring via the subsystem direct access OSE test connectors, during major module-subsystems integration tests, (Phase 1A) and, major module integration tests, (Phase 1B). The G&C SSTS may also be used to perform Pre-Delivery Acceptance (PDA) testing of the flight G&C subsystem at the vendor's plant.

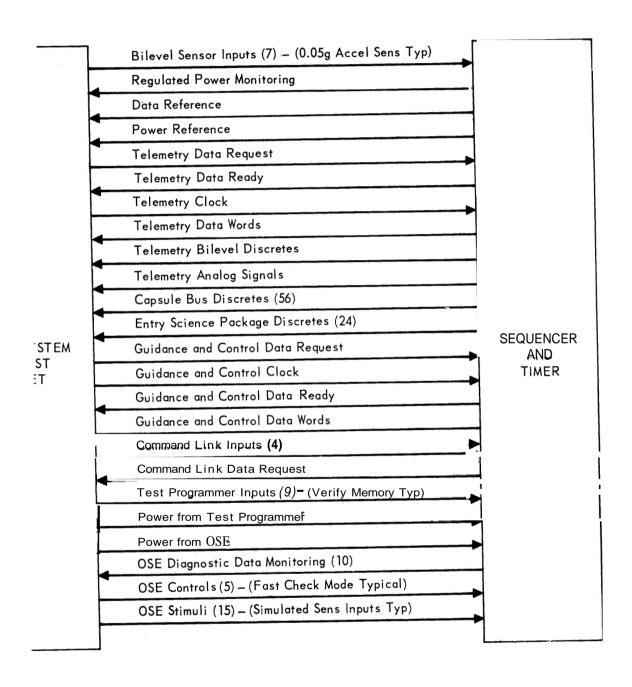
One (1) set of the G&C subsystem test equipment is required at the KSC industrial area for contingency purposes.

- 5.5.2 <u>Design Requirements</u> The G&C subsystem test set functional design requirements are:
 - a. Simulating radar inputs to the G&C flight subsystem.
 - b. Electrically simulating vehicle movement by providing torquer signals to the gyros and accelerometers.
 - c. Simulating Sequencer and Timer inputs for mode control and computer memory write-in, update and readout.
 - d. Simulating in-flight test programmer commands and digital words.
 - e. Supplying power.
 - f. Monitoring and supplying loads for the G&C output signals to terminal propulsion, reaction control and de-orbit subsystems.
 - g. Supplying diagnostic input stimuli and monitoring data provided by the subsystem OSE test connectors.
 - h. Monitoring and supplying loads for the TM output signals.

SEQUENCER SUBSYSTEM TEST SET INTERFACE DIAGRAM



5-19-1

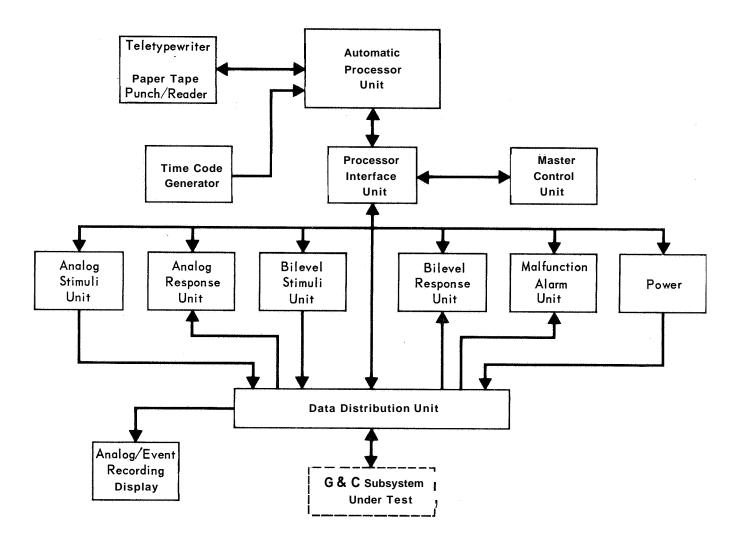


- 5.5.3 Physical Characteristics The G&C Subsystem Test Set (SSTS) arrangement is shown in Figure 5.5-1, The test set is constructed to be easily disconnected and connected into the test complex cabling, facilitating transportation. The test set incorporates standard modules, which are of common design for major subsystem test set usage. i.e., automatic processor unit, malfunction alarm unit, etc. The construction features growth-provisions, safety interlocks, fault isolation test points and plug in components to implement human engineering factors and maintainability concepts. The test adapter unit, shown in Figure 5.5-1 is used for connecting the G&C elements directly into the test set for PDA and EFC testing. Extension cables are provided to allow calibration/verifications to be preformed on the G&C elements, in conjunction with environmental chambers and rate/position tables at the vendor. The test set is functionally grouped and supported by a castered structure for mobility.
- Operational Description A block diagram of the test set is shown in Figure 5.5-2 and identifies the following major functioning elements;
 - a. Automatic Processor Unit: Provides for automatic test sequence control and instrumentation set up, data GO/ON GO comparisons and OSE self-check routines. The teletypewriter and paper tape punch/reader art: used for automatic processor input/output.
 - b. Analog Stimuli Unit: Provides programmable signal generators for analog stimuli application to the G&C subsystem.
 - c. Analog Response Unit: Provides an analog multiplexer, analog to digital converter and signal conditioning for measurement of analog parameters. The multiplexer is of the "on demand" type to implement high sampling rates of defective or out of tolerance parameters.
 - d. Bilevel Stimuli Unit: Provides programmable bi-level sources £or discrete commands.
 - e. Bilevel Response Unit: Provides bi-level sensors for monitoring discrete parameters.
 - f. Malfunction Alarm Unit: Provides analog and bi-level, settable hi/lo detectors for continuous monitoring of key/critical parameters. Visual/ audible alarms are used for indication of key parameter status with an automatic shut down routine for critical conditions.
 - g. Analog/event recorders/displays: Provides for selective recording/display of analog/bi-level parameters for time line plots.

'GUIDANCE AND CONTROL SSTS

		,
Analog Stimuli Unit	Malfunction Alarm Unit	
Analog Response Unit	Bilevel Stimuli Unit	
Data Distribution Unit	Bilevel Response Unit	
Test Adapter Unit	Master Control Unit	
Writing	Surface	
Analog/Ev _{ent} Chart Recorder	Processor .Interface Unit	Automatic Processor Unit
	DC Power Supplies	Time Code Generator
Blower	Blower	Blower

GUIDANCE AND CONTROL SSTS FUNCTIONAL BLOCK DIAGRAM



- h. Power: Provides a programmable power supply for performance margin subsystem tests.
- i. Time Code Generator: Provides for time-tagging recorded/printed data in real time.
- j. Processor Interface Unit: Provides for data input/output to the processor, generates and receives digital data associated with the G&C computer and stores digital data for subsequent automatic processing.
- k. Data Distribution Unit: Provides flexibility in signal routing between the subsystem under test and the test set modules.
- 1. Master Control Unit: Provides manual controls and displays for operating the test set in its automatic and manual modes and includes thumbwheel switches for setting in subsystem component serial numbers and other test information, for use by the data bank.

Additional descriptions of modules commonly used in subsystem test sets are described in paragraph 5.2.

The test set bi-level stimuli unit supplies the required discrete commands for initiating G&C subsystem events, such as operating and in-flight checkout modes. The processor interface unit, (in conjunction with the sutomatic processor) supplies digital words for inputs to the G&C computer, such as computer instructions and memory update. The G&C computer has a memory capacity of 4096 20-bit words, which are loaded, updated and readout by commands and digital instructions provided by the test set.

Radar velocity, range and altitude digital input signals to the G&C are supplied by the processor interface unit. Radar status signals are simulated by the bilevel stimuli unit.

The Inertial Measurement Unit outputs, (digital data trains) are gated into registers located in the processor interface unit for determining events per unit time corresponding to gyro and accelerometer dynamic/static displacements, Precision gyro and accelerometer torquer input signals are supplied by the processor interface unit (digital data) for application to the gyros and accelerometer for calibration and simulation of vehicle movement. The G&C outputs are bi-level signals for control of the reaction control system thruster solenoids and proportional digital signals for throttling the terminal propulsion system engines all of which are verified by the test set response units, The test set event recorder can be used to monitor the G&C output signals for correlation of these

signals with the appropriate input stimuli or computational mode of the G&C computer.

- 5.5.5 <u>Interface Definition</u> The functional interfaces between the G&C flight subsystem and the G&C subsystem test set are shown in Figure 5.5-3.
- 5.6 RADAR SUBSYSTEM TEST SET (SSTS) The Radar SSTS includes both the Landing Radar Test Set and the Radar Altimeter Test Set. Because of the similarity of function, operation and utilization, the test sets are combined to share an automatic processor unit. The features that are peculiar to either landing or altimeter test set are pointed out in the discussion.
- 5.6.1 <u>Identification and Usage</u> The Radar Subsystem Test Set provides power, control, monitoring and recording equipment necessary to test the Radar Subsystems during pre-delivery acceptance (PDA) tests, equipment functional checks (EFC), and subsystem tests. No additional test equipment or subsystems are required to be connected or operating in order to perform these tests.
- 5.6.2 <u>Design Requirements</u> The test set is required to provide a means of coupling RF energy between the test set cabinets and the subsystem antennas. It also is required to provide a means to contain the test-set-generated RF energy and the subsystems-generated RF energy necessary to perform simulated mission tests and RF measurement tests.
- 5.6.3 <u>Physical Characteristics</u> The test equipment is comprised of three standard electrical cabinets of landing radar test equipment, three standard electrical equipment cabinets of radar altimeter test equipment, an antenna hat coupler for each of the two subsystem's antennas, and an automatic processor console which interfaces with both sets of cabinets. The cabinets and console are mounted on castered bases and are illustrated in Figure 5.6-1. The antenna hat couplers are shown in Figure 5.6-2.
- 5.6.4 Operational Description In operation the test set selects the test point to be measured, provides excitation and stimulation, sets up the type of measurement and range, provides evaluation limits and comparison circuits, provides for data recording, supplies a timing reference and mark, and provides all required commands displays and power.
 - 5.6.5 <u>Performance Characteristics</u> The test set block diagram, shown in Figure 5.6-3 is designed to perform the following functions:

<u>Control</u> - Control is either manual or automatic. Automatic control is accomplished with an automatic processor comprised of a computer, comparison

GUIDANCE AND CONTROL TO SSTS INTERFACES

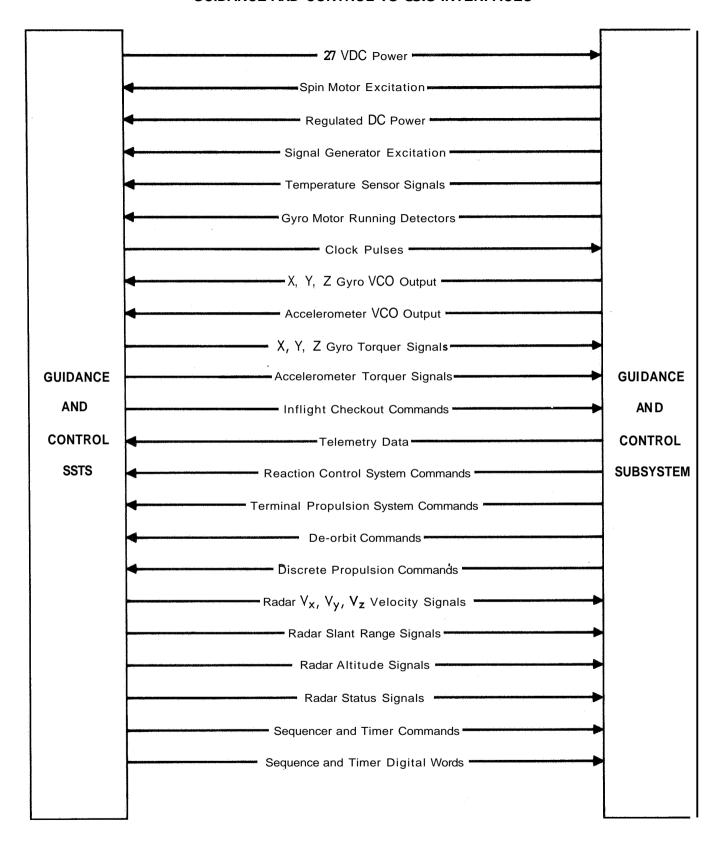


Figure 5.5–3 5–25

RADAR SUBSYSTEM TEST SET

Simulation Circuitry			Signal Conditioning			Oscillators OSE Power Supply Blower			Blower				
	Spectrum Analyzer		Data Converter		Test Point Selector	Test	Adaptor	Writing Surface	Comparison Circuits	<u>.</u>	Landing Radar	Power Supply	Blower
Circuit Breaker	Power	Meter	Displays		Visual and Audio Alarms		Control		Analog Recorders		OSE	Power Supply	Blower
AUTOMATIC PROCESSOR													
Circuit Breaker	Power	Meter	Displays		Visual and Audio Alarms		Control		Analog		Radar Altimeter	Power Supply	Blower
Comparison	Circuits		Spectrum Analyzer	Signal	Conditioning Test Point Selector	Test	Adaptor Unit	Writing Surface	Simulation Circuitry	Oscillator	OSE	Power Supply	Blower

Figure 5.6-1

5-26

Figure **5.6–2**

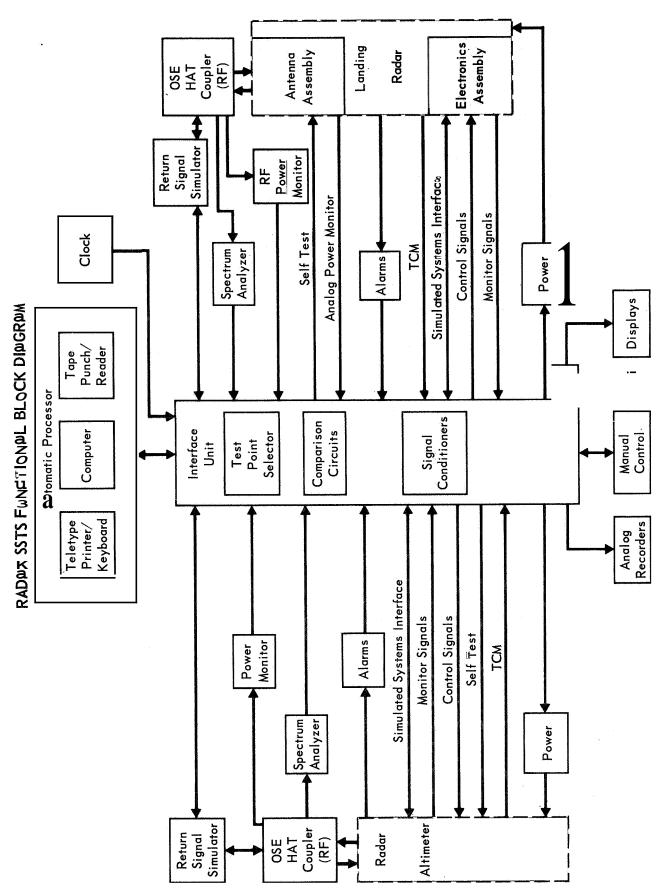


Figure **5.6-3**

circuits, and a teletypwriter with attached tape punch and reader for memory loading, programing inputs and printout.

<u>Simulation</u> - The test set is designed to provide authentic RF simulation of radar return signals expected during a Martian landing. RF frequencies are X-band for landing radar and L-band for the radar altimeter. A wide range of signal frequencies, bandwidths and signal levels can be programmed with a dynamic range simulator to simulate any specified descent trajectory. The signals to be simulated at high altitudes are generally characterized by low power levels and wide signal bandwidths, whereas at low altitudes, high level signals with narrow bandwidths are expected. This test equipment has the capability of simulating signal characteristics at discrete points during the mission, and reading out the corresponding radar outputs. Simulation of all loads and signals seen by the Radar Subsystem interfaces is provided by the test set.

Measurement - As indicated in the interface diagrams of Figures 5.6-4, and -5, the test equipment measures radar frequency, spectrum, power, sensitivity, telemetry outputs, discrete outputs, AGC, AFC, and response to interrogation and stimulation. Pulse risetime, pulse width, pulse repetition frequency, and peak power of the Radar Altimeter are measured, while on the Landing Radar, deviation frequency, and modulator sweep amplitude and frequency are measured.

Comparison - The equipment compares the measured values against programmed limits and provides a GO/NO GO evaluation, a record (punched tape) of the measured value, a digital display, and a teletype printout of any out-of-tolerance measurement.

<u>Recording</u> - All test measurements are recorded on punched tape. Additional analog and digital recording are provided where necessary. Flight subsystem and test equipment operating times are also recorded.

<u>Self-Test</u> - OSE self test is performed automatically at the beginning and end of each program and verification is performed at any no-go hold. Self-test is provided by simulating the Radar Subsystems' functions which are measured or controlled by the test equipment, and by checking the response of all monitor and tolerance detectors to both marginal and nominal conditions of the simulated functions and the applied stimuli.

<u>Built-In-Test</u> - The BIT of both radar subsystems contains the necessary components to supply simulated targets at the RF level (and at the IF level for landing radar) for receiver checkout. The BIT is controlled by the test set during checkout and is used as an aid in obtaining test measurements.

LANDING RADAR SSTS INTERFACE

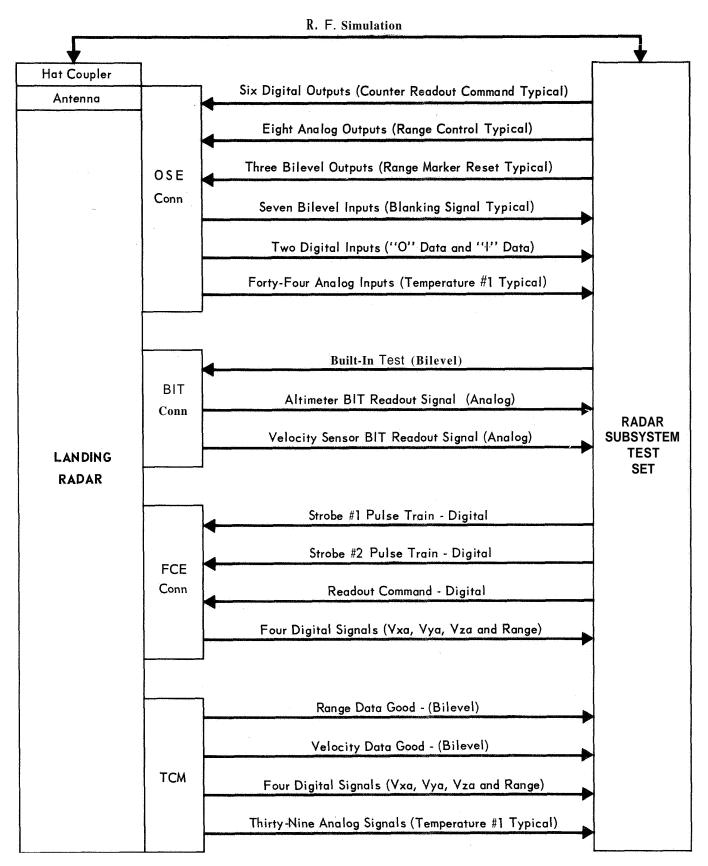


Figure **5.6-4**

RADAR ALTIMETER SSTS INTERFACE

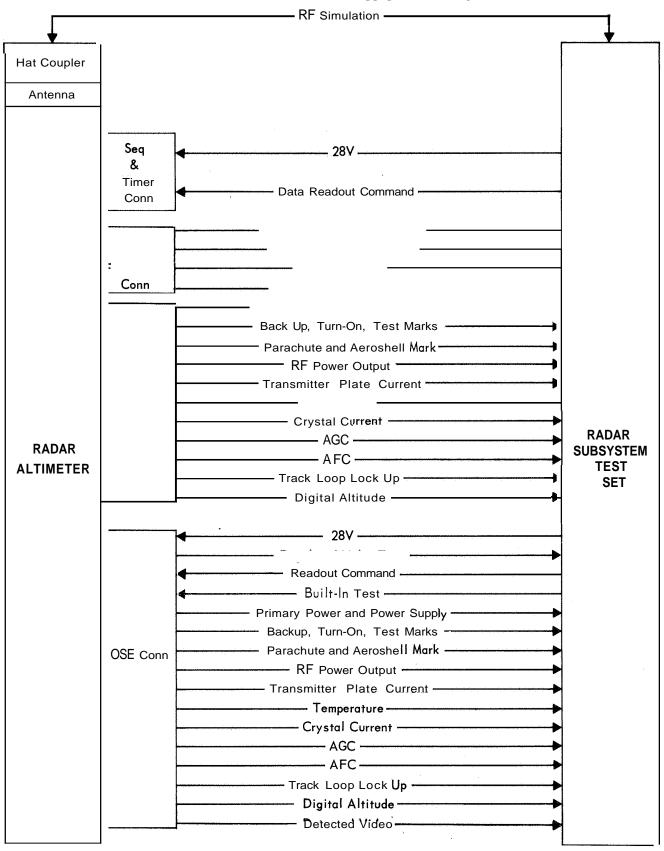


Figure **5.6-5**

<u>Critical Alarm Monitoring</u> - Continuous monitoring of critical parameters is provided to determine if the parameters are in tolerance. Visual and audio alarm indications are provided to indicate out-of-tolerance conditions. In addition, provisions are made to prevent application of destructive out-of-tolerance stimuli and to isolate sensitive elements from critical conditions.

<u>Telemetry Data Monitoring</u> - Provision is made to measure directly on Radar Subsystem outputs normally monitored in-flight by telemetry.

- 5.6.6 Interfaces RF coupling between the test set and the radar antenna subassemblies is achieved by use of the antenna hat couplers as shown in Figure 5.6-2. These are, in each case, a single unit attached to the antenna assembly(s) with complete DC electrical isolation maintained between the coupler and the antenna assembly(s) by use of isolation pads. The hat extracts microwave energy from the transmitter arrays, in the case of the Landing Radar, and allows modulated energy to be coupled back into the receiver arrays; it provides the RF interface between the test set and the antenna in the case of the Radar Altimeter. Subsystem interface information is shown in Figure 5.6-4 and Figure 5.6-5. Individual subassemblies are connected directly to the test set by mounting the subassembly on the test adaptor unit which is a part of the test set. Signal quantities shown on the interface diagrams are approximate.
- 5.7 TELECOMMUNICATION SUBSYSTEM TEST SET
- 5.7.1 Equipment Identification and Usage The telecommunications Subsystem

 Test Set is used to acceptance test the following Capsule Bus TCM Subsystems as individual subsystems or as a combined TCM subsystem:
 - a. Command
 - b. Data Storage
 - c. Telemetry
 - d. Radio
 - e. Antenna

In addition, the test equipment is used for compatibility and qualification testing of the Capsule Bus TCM Subsystems, for flight capsule integration and functional testing at the CB contractor's facility and for contingencies at KSC.

- 5.7.2 <u>Design Requirements and Constraints</u> The following functions are required of the Telecommunications SSTS:
 - a. Provide simulated CB engineering analog and digital data to enable testing of the telemetry multiplexer.

- b. Provide simulated ESP 282 bps serial RM data to enable testing of the multiplexer during simulated entry and landing mission phases.
- c. Provide two UHF receivers for receiving the FSK-modulated RF carriers from the radio subsystem.
- d. Demodulate the **FSK** subcarrier and provide a serial RM (Manchester Code) bit stream of telemetry data.
- e. Provide decommutation of the telemetry data in simulated entry, cruise and in-flight checkout modes at data rates varying from 7.0 bps to 2730 bps.
- f. Provide a capability for displaying selectable telemetry channels for "quick look" analysis.
- g. Provide the capability to record on a magnetic tape the two FSK telemetry subcarriers.
- h. Interface with an automatic processor for test sequence control.

The equipment that accepts external control in this mode are:

1. Telemetry Controller

7. TM data selector

2. DVM input selector

8. Display unit

3. Counter input selector

9. CB mode control

4. Printer input selector

10. CB TM generator

5. FSK data selector

11. ESP TM generator

- 6. Magnetic tape recorder
- 5.7.3 . Physical Description The CB TCM SSTS is housed in seven standard electronic equipment cabinets as shown in Figure 5.7-1. The total weight of the test set is approximately 2350 pounds. AC power consumption is approximately 5200 watts.
- 5.7.4 Operational Description The CB TCM Subsystem Test Set provides manual or computer controlled checkout of the combined TCM subsystems. This equipment also provides manual checkout of the individual TCM subsystems and their elements. A functional block of the SSTS is shown in Figure 5.7-2.

In the automatic mode, the automatic processor provides instructions from the test program, reads addresses and routes the instructions to the proper portion of the test set for execution. The processor also selects the source of data for external logging and processing. Data is available from the digital voltmeter, counter or telemetry processing equipment. All portions of the test equipment which are controllable by the automatic processor are also capable of manual control.

TELECOMMUNICATIONS SUBSYSTEMS TEST SET

AC Power Control	AC Power Control	Data Starras	AC Power Control
	Capsule Bus TM Data Generator	Data Storage Subsystem Control Panel	Counter and Input Selector
Magnetic Tape Transport	Capsule Bus Command Subsystem Control and Monitor Panel	TM Subsystem Control Panel	Spectrum Analyze r
	Capsule Bus Mode Control	Radio Subsystem Control Panel	UHF Receiver
Tape Control	ESP TM		UHF Receiver
Record/Reproduce Electronics	Data Generator		FSK Data Selector
	Power Supply	Power Supply	

Figure 5.7**–**1

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			e F
RF	AC Power Control	TM Signal Simulator	
Patch Panel	Data Patch Panel		
Oscilloscope	Data	TM Frame Synchronizer	
RMS Voltmeter	Display	Data Distributor	
Volumeter		TM Subframe Synchronizer	
Wave Analyzer	Digital Voltmeter	TM Subframe synchronizer	
	DVM Input	TM Subframe Synchronizer	AND ESSECTION
	Selector	TM Subframe Synchronizer	
	Printer Input Selector	TM Subframe Synchronizer	
		TM Subframe Synchronizer	
,	Printer	TM Controller	
Power Supply		Power Supply	
			Automatic Processor

TCM SSTE FUNCTIONAL BLOCK DIAGRAM

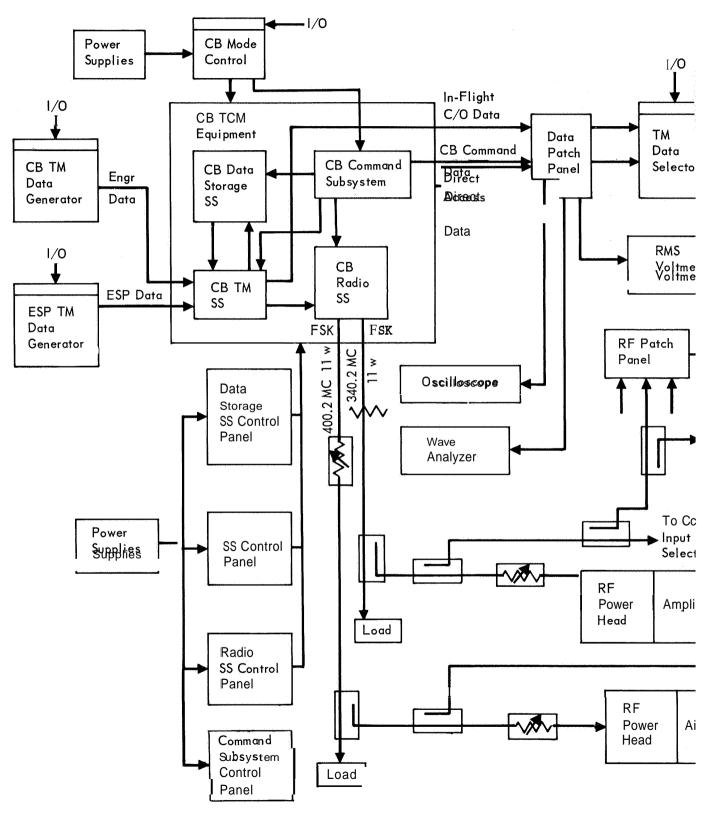
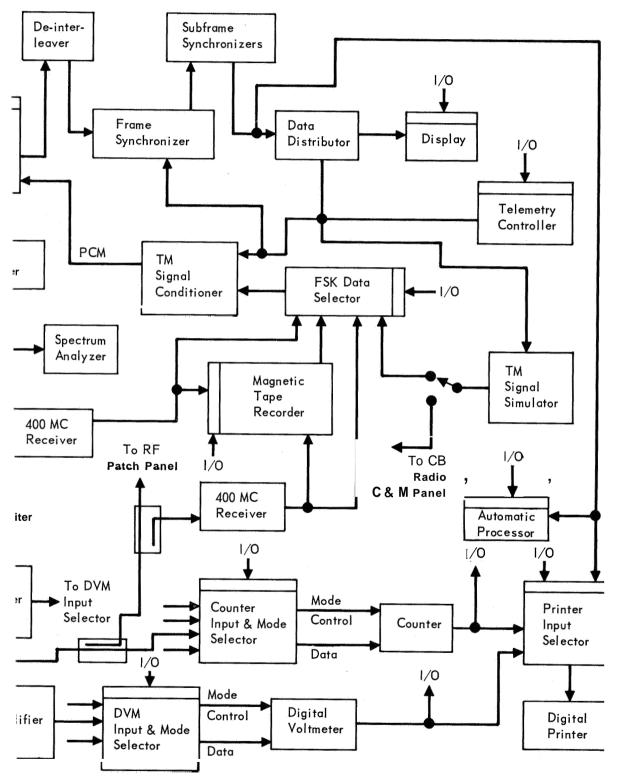


Figure **5.7–2**

5-35-



I/O = Automatic Processor Input/Output interface

The CB mode control panel supplies the power and control stimuli necessary to exercise the combined subsystems in all of their operational modes.

The telemetry data generators provide simulated data as inputs to the CB telemetry subsystem. The CB TM generator provides analog inputs and digital inputs; the ESP TM generator provides digital data at 282 bps as a digital input to be multiplexed by the CB TM subsystem.

All outputs from the combined subsystem are routed to a patch panel for distribution to the test equipment. Each RF output from the Radio Subsystem is routed to an RF power meter, the counter input selector, patch panel, and a test receiver. The TM signal conditioner detects the FSK signal from the receiver and supplies the RM serial data to the TM data selector. This unit selects the in-flight checkout data, CB cruise data, or the TM data to be processed, displayed, and recorded. The data distributor and display panel provide for serial-to-parallel conversion and display of up to 32 selectable data words.

The test receivers are designed to perform the following functions:

- a. Simulate spacecraft-to-capsule link space loss.
- b. Provide a baseband output for telemetry demodulation.
- c. Provide for monitoring of the received signal.
- d. Provide for monitoring test receiver operation.

Two test receivers are provided to facilitate simultaneous recording of both diversity FSK signals on a multichannel magnetic tape recorder. The capability is also provided to record the decommutated RM serial data.

The telemetry processing portion of the SSTS consists of the following:

- a. Controller
- b. Signal simulator
- c. Signal conditioner
- d. Frame synchronizer
- e. Data distributor
- f. Subframe synchronizers

The controller is manually or automatically controlled. This unit automatically sets up the proper bit rate, input code, polarity, detector type, phase locked loop width, capture and tracking range and output code of the TM signal simulator, the TM frame and subframe synchronizers, the data distributor, and the TM signal conditioner (demodulator). During the manual operating mode, and in testing the individual TCM subsystem, the parameters are selected by manual switches on the equipment front panels.

The DVM input selector, counter input selector and printer input selector provide manual or automatic control of the data being supplied to the respective units. In the case of the DVM and counter, the range and function are also controlled by the input selectors. The magnetic tape recorder records decommutated telemetry data during simulated cruise, in-flight checkout, de-orbit cruise, de-orbit thrust, entry, and terminal descent modes. Data from the DVM and counter are recorded on punched paper tape and the teleprinter. Data recording is in real time.

Provisions are made for automatic or manual self-check of the OSE. Self-checks are performed without test interruption. The DVM and counter input selectors contain calibrated input positions. Calibration can be verified by the automatic processor at the instrument output, by printout on the printer, and also by visual readout. The telemetry processing equipment can be checked by setting known inputs into the TM simulator and by checking the output on the printer and/or display unit or the subframe synchronizer output.

A control and monitor panel is provided for each subsystem for controlling and routing power and test stimuli to the subsystem under test. Inputs to the subsystem are made to both flight and direct access connectors. The outputs are monitored by proper configuration of the telemetry processing equipment and RF monitoring equipment. The test requirements of the TCM subsystem are listed in Figures 5.7-3, -4, -5 and -6.

- 5.7.5 <u>Interfaces</u> The SSTS interfaces with the TCM subsystems as follows:
 - a. <u>Individual Subsystem Testing</u> Interfaces are made at both flight and direct access connectors. The SSTS supplies all stimuli and monitors responses. See Figure 5.7-7.
 - b. Combined Subsystem Testing Interfaces are made at direct access connectors and at flight connectors that interface with other subsystems. Stimuli are simulated TCM data and commands. Responses are checked by monitoring direct access functions and telemetry data train. The interfaces are shown in Figure 5.7-8.

TELEMETRY SUBSYSTEMS TEST REQUIREMENTS

TESTS	MEASURING INSTRUMENT	<u>ACCURACY</u>
Cruise Commutators:		
Power Supply Voltage	Digital Voltmeter	3%
Power Supply Current	Digital Voltmeter	3%
Input Clock	Scope/TM Signal Simulator	Digital
Commutation Sequence	TM Processing Equipment	Digital
Input Analog Signals	Digital Voltmeter	1%
Spurious Outputs	Oscilloscope	0.1%
Data Output	TM Processing Equipment	1%
ADC/Multiplexer:		
Power Supply Voltage	Digital Voltmeter	3%
Power Supply Current	Digital Voltmeter	3%
Input Voltage	Digital Voltmeter	1%
Conversion Accuracy	TM Processing Equipment	1%
Operational Sequences	TM Processing Equipment	Digital
Digital Miltiplexer:		
CB/ESP Data Interleaver		
Power Supply Voltage	Digital Voltmeter	3%
Power Supply Current	Digital Voltmeter	3%
Input Data	Scope/TM Signal Simulator	Digital
Output Data	Scope/TM Processing Equipment	Digital
Interleaving Operation	TM Processing Equipment	Digital
FT/DT Data Interleaver:		
Power Supply Voltage	Digital Voltmeter	3%
Power Supply Current	Digital Voltmeter	3%
Input Data	Scope/TM Signal Simulator	5% Digital
Output Data	Scope/TM Processing Equipment	5% Digital
Interleaving Operation	Scope/TM Processing Equipment	5% Digital
Clock Generator:		
Power Supply Voltage	Digital Voltmeter	3%
Power Supply Current	Digital Voltmeter	3%
Reference Oscillator	Counter	Digital
Output Clock Signals	Scope/Counter/TM Processing Equipment	Digital

Figure **5.7–3**

RADIO SUBSYSTEM TEST REQUIREMEMENTS

<u>TEST</u>	MEASURING INSTRUMENT	<u>ACCURACY</u>
RF Power Output	PWR Meter	0.2 db
Power Amplifier Collector Current	DVM	2%
Power Supply Voltage	DVM	0.1%
DC Current Drain	DVM	2%
Case Temperature A	DVM	2%
Case Temperature B	DVM	2%
Modulation Input	Scope/TM Processing Equip- ment	5%
Spurious Output	Spectrum Analyzer	1 db
Transmitter No. 1 Frequency	Counter	1 x 10 ⁻⁸
Transmitter No. 2 Frequency	Counter	1 x 10 ⁻⁸
AGC Voltage	DVM	2%
Detected RF Output	DVM	0.5 db
RF Power Stability	PWR M eter	0.2 db
Frequency Stability	Counter	1×10^{-8}
VSWR Monitor	DVM	2%

DATA STORAGE SUBSYSTEM TEST REQUIREMENTS

TEST	MEASURING INSTRUMENT	<u>ACCURACY</u>
Entry Data Storage		
Power Supply Voltage	DVM	3%
Power Supply Current	DVM	3%
Input Data	Scope/TM Processing Equip- ment	Digital
Memory Operation	Scope/TM Processing Equip- ment	Digital
Memory Control Signals	Scope/TM Processing Equip- ment	Digital
Output Data (50 sec delay)	Scope/TM Processing Equip- ment	Digital
Output Data (150 sec delay)	Scope/TM Processing Equip-	Digital
	ment	

Figure **5.7-5**

COMMAND SUBSYSTEM TEST REQUIREMENTS

TEST	MEASURING INSTRUMENT	<u>ACCURACY</u>
Power Supply Voltage	Digital Voltmeter	3%
Input Command Data Word	Scope/TM Signal Simulator	Digital
Parity	Digital Voltmeter	3%
Decoded Command	Scope/TM Processing Equip- ment	Digital
Bit Sync	Scope/TM Processing Equip- ment	Digital
Command Event	Scope/TM Processing Equip- ment	Digital

Figure **5.7–6**

TCM SSTS INTERFACE (COMPONENT TESTING)

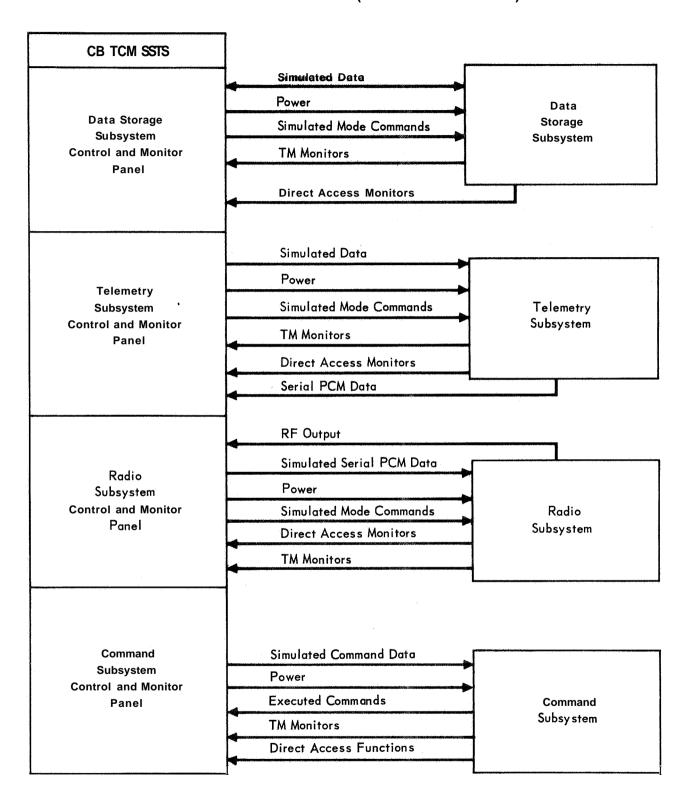


Figure 5.7-7

TCM SSTS INTERFACE (SUBSYSTEMS TESTING)

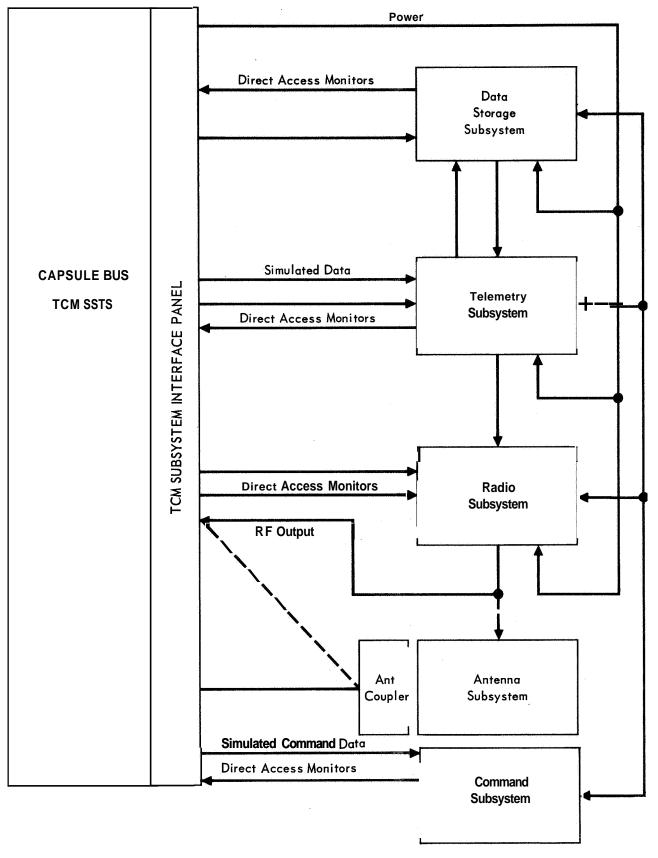


Figure 5.7-8

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5.8 THERMAL CONTROL SUBSYSTEM TEST SET

- 5.8.1 <u>Equipment Identification and Usage</u> This equipment is used to test the Capsule Bus Thermal Control Subsystem during the following test phases:
 - a. At the contractor's facility for functional checkout of the Thermal Control Subsystem.
 - b. Subsystem-level testing during major module buildup at the Capsule Bus contractor's facility.
 - c. For contingency support at KSC.
- 5.8.2 Physical Characteristics The SSTS consists of two units: the Thermal/Electrical Test Set and the Emissivity/Reflectivity Test Set. The Thermal/Electrical Test Set is contained in one standard electronic equipment cabinet and weighs approximately 500 pounds. The Emissivity/Reflectivity Test Set is contained in a mobile cabinet (caster mounted) and weighs about 230 pounds. The two tests sets are illustrated in Figure 5.8-1.

5.8.3 Operational Description

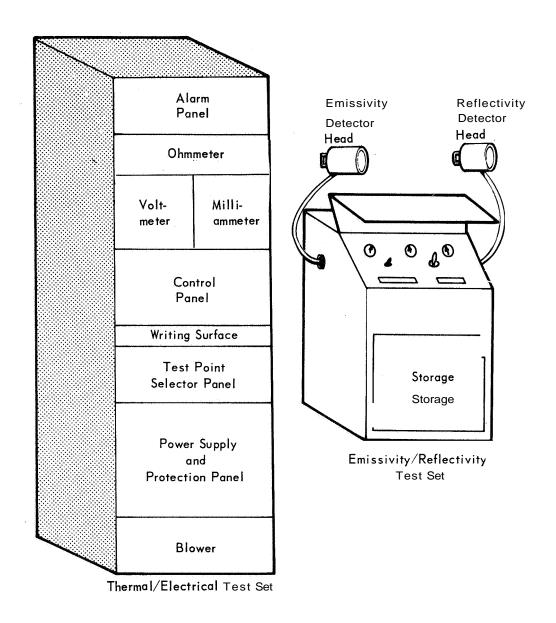
5.8.3.1 <u>The Thermal/Electrical Test Set</u> - The Capsule Thermal Control Subsystem consists of thermostatically-controlled electric heaters in combination with blankets of insulating material and special thermal coatings on selected surfaces.

The selected means of testing the thermostatically-controlled heaters consists of thermally cycling the flight temperature-sensing elements (thermocouples) and measuring the input power and/or the electrical resistance of the subsystem heater elements.

The temperature cycling of the thermocouples is accomplished by means of heat probes which are mounted adjacent to the thermocouples. The heat probe is a thermoelectric device, electrically driven to produce a lower or higher temperature than the set point temperature of the control system associated with the sensing thermocouple. This provides remote operation of each sensing thermocouple and each of the associated control circuits which operate the subsystem heater power ON and OFF switches.

A block diagram of the Thermal Control Subsystem Test Set is shown in Figure 5.8-2. Controls are provided for varying the temperature of the heat probes. Self-test features are included in the test equipment. The circuit selector switches provide a means of connecting these control and measuring instruments to the various heat probes and heater circuits of the CB. Critical circuits contain protective sensors for overvoltage and excessive temperatures.

THERMAL CONTROL SUBSYSTEM TEST SET



.Figure 5.8-1

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THERMAL CONTROL SSTS FUNCTIONAL BLOCK DIAGRAM

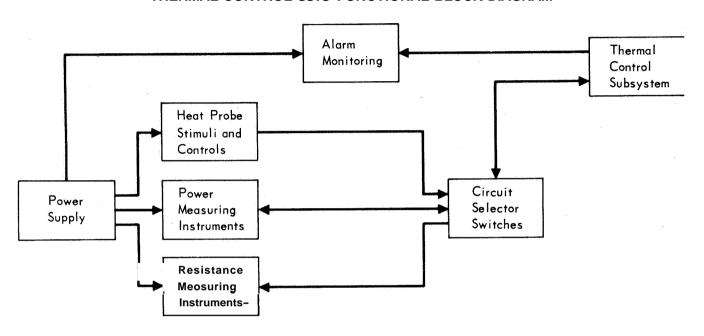


Figure 5.8-2

THERMAL CONTROL SSTS. INTERFACE

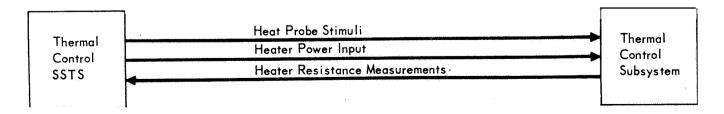


Figure 5.8-3

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the specially coated surfaces is to measure their emissivity and reflectivity. These measurements are made with hand-held detectors that interface directly with the surface under test. The emissivity detector measures the emittance of an opaque surface at room temperature. The detector is composed of a radiometer and a heat source for the surface to be measured and is connected to the main cabinet with a flexible conduit. When the radiometer opening is covered, the detector has an output proportional to the infrared emittance of the surface. This output is indicated on a self-balancing potentiometer in the cabinet.

The reflectivity detector head measures the reflectance of an opaque surface at room temperature. The detector provides radiation from a xenon lamp which is filtered and directed into an integrating sphere. When this radiation is directed onto a surface placed over the sample port, the sphere detector has an output proportional to the amount of reflected radiation. This output is read by the indicating potentiometer in the cabinet. Special surfaces are supplied for self-test and calibration of the set.

- 5.8.4 <u>Interfaces Definitions</u> The Thermal/Electrical Test Set makes electrical connection to the CB Thermal Control Subsystem through the OSE connectors. Interface connectors are summarized in Figure 5.8-3. The Emissivity/Reflectivity Test Set detector heads are physically placed on the thermally coated surface for both radiation and reflection measurements.
- 5.9 PYROTECHNIC SUBSYSTEM TEST SET
- 5.9.1 <u>Identification and Usage</u> The Pyrotechnic Subsystem Test Set is used to perform equipment functional checks (EFC) at the Capsule Bus contractor's plant prior to the Pyrotechnic Subsystem's installation into the Capsule Bus and to provide direct subsystem control and monitoring via the subsystem OSE test connectors during major module integration tests (phase 1A and 1B). Elements of the test set, i.e., Electro-Explosive Device (EED) simulators and test batteries, are used for simulated mission tests (Phase 11) in the Class 100 clean room, and in the environmental chamber. Pyrotechnic subsystem test equipment is required at KSC industrial area and explosive-safe facility.

5.9.2 <u>Desipn Requirements</u>

The Pyrotechnic Subsystem Test Set requirements are as follows: PDA/EFC Level:

- a. Simulate sequencer commands
- b. Simulate CB power and pyro battery power
- c. Monitor bilevel output signals and simulates loads

- d. Measure continuity of shields and grounds.
- e. Monitor TM output signals.
- f. Measure resistance of firing circuits and current limiting resistors.
- g. Determine the ability to all-fire/no-fire EED's.

Installed subsystem-level:

- a. Measure stray voltages.
- b. Measure EED bridge wire resistance via the OSE test connectors.
- c. Measure continuity of shields and grounds.
- d. Measure resistance of firing circuits and current limiting resistors.
- e. Monitor charge, arm and fire circuitry via the OSE test connectors.
- f. Determine the ability to all-fire/no-fire EED's.
- g. Simulate pyro battery power.
- h. Provide pyro test batteris and support equipment for the maintenance and use of the batteries.
- 5.9.3 Physical Characteristics The Pyro Subsystem Test Set arrangement is shown in Figure 5.9-1. The test set is constructed to be easily disconnected and connected into the test complex cabling, facilitating mobility. The design features growth provisioning, safety interlocks, fault isolation test points and plug-in components to implement human engineering factors and maintainability concepts. The rack is caster mounted.
- 5.9.4 Operating Description The Pyro Subsystem Test Set block diagram is shown in Figure 5.9-1 and identifies the major functioning elements of the test set as follows:
 - a. <u>Voltmeter</u>: The voltmeter is used to measure EED control module output firing voltage levels, voltage signals associated with the OSE test connector and stray voltage at the pyrotechnic connectors located in the flight subassemblies. The voltmeter has a measuring frequency range of DC-to-radio frequencies, an input resistance of approximately 1,000 ohms and ranges of 5 millivolts to 50 volts.
 - b. Ohmmeter: The ohmmeter is used to measure EED bridge wire (BW) resistance, (approximately one ohm), shield and ground continuity, and resistance of the series current-limiting resistors. The ohmmeter uses a low current-limiting circuit for measurement of BW resistance. The ohmmeter is also used to determine if EED simulators have fired during assurance tests by reading BW closed or open circuit resistance.

PYROTECHNIC SUBSYSTEM TEST SET

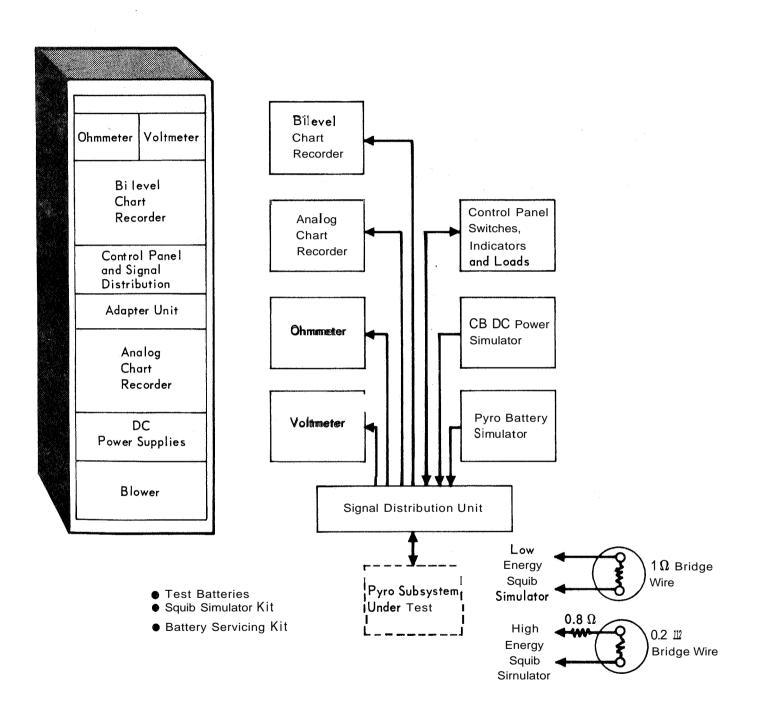
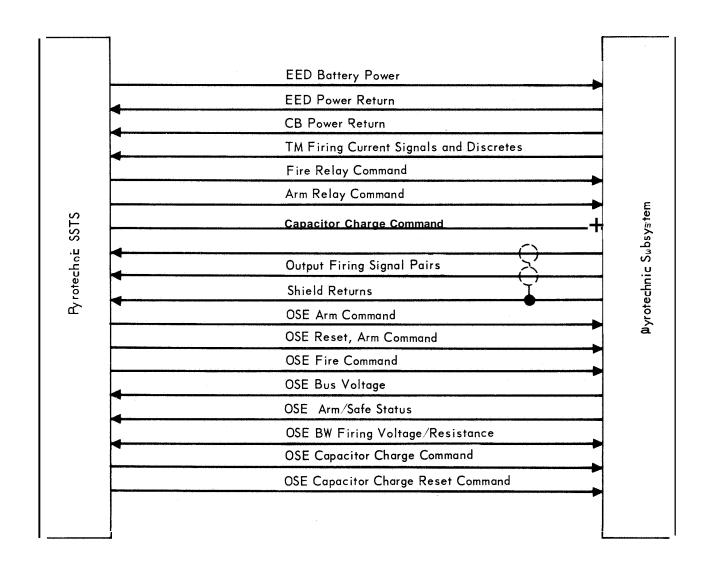


Figure **5.9-1**

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- C. <u>CB Pyro Battery Power</u>: Variable-voltage power supplies are used to simulate CB and pyro battery power for performance margin testing.
- d. Controls, Indicators & Signal Distribution: Control panel toggle and push button switches provide for simulation of sequencer commands to the EED control modules and for actuation of the ARM, CHARGE and fire relays. Indicator lamps, in conjunction with EED simulated loads are used to monitor the bilevel output signals. The routing of input/output signals to the test set instruments are provided for by a patch panel-signal distribution unit. The adapter unit shown in Figure 5.9-1 is used to connect the EED control modules directly into the test set for EFC testing. Extension cables are provided for connecting the test set to the installed EED control modules, OSE test connectors and to the pyrotechnic connectors located in the flight assemblies,
- e. <u>Event Recorder</u>: The event chart recorder is used to provide time line plots of bilevel TM signals, relay status, and pyro firing signals for the installed subsystem level tests.
- f. <u>Test Batteries</u>: Test batteries are provided to simulate the flight pyro auto-activated batteries for simulated mission tests.
- g. <u>Squib Simulators</u>: High Energy Squib Simulators (HESS) and Low Energy Squib Simulators (LESS) are installed directly into the flight pyro connectors for use in system assurance and simulated mission tests for determining the subsystem's ability to fire a high energy EED and not to fire a Low Energy EED under RF Radiation conditions. The activation of these devices does not result in the discharge of contaminants. HESS and LESS devices act as fuses, i.e., blow at a given energy level and provide a visual indication of the bridge wire status.
- h. Analog Recorder: The analog chart recorder is used to measure the TM firing current output signals. These signals are voltage pulses obtained through transformer action as a result of firing current. (The current transformers are integral to the EED control module.) Calibration of these signals is provided by comparison of the TM output amplitudes with measured firing current.
- 5.9.5 <u>Interface Definition</u> The functional interfaces between the pyro subsystem and the pyro subsystem test set is shown in Figure 5.9-2.

PYROTECHNIC SSTS INTERFACES



- 5.9.6 <u>Safety Considerations</u> The handling and installation of pyrotechnics and CB testing with pyrotechnics (EED's) will be in accordance with the Capsule Bus contractor's safety plan. Whenever live pyrotechnics are installed, pyro shorting plugs are installed to prevent accidental firing.
- 5.10 PROPULSION SUBSYSTEM TEST SET
- 5.10.1 <u>Identification and Usage</u> The Propulsion Subsystem Test Set is used to perform equipment functional tests, subsystems-level and system-level tests on the Terminal Propulsion Subsystem (TPS) and Reaction Control Subsystem (RCS) at the CB contractor's factory, and to perform system-level tests at KSC. In addition the equipment is used for leakage testing of the Canister, TPS and RCS.

 5.10.2 <u>Design Requirements and Constraints</u> The Propulsion Subsystem Test Set functional requirements are as follows:
 - a. Measuring internal and external gaseous leakage of all elements at the equipment functional test level.
 - b. Checking functional operation of pressure transducers, temperature transducers, pressure regulators, check valves, relief valves and thrust chamber assemblies at the equipment functional check test level.
 - c. Calibrating pressure transducers, temperature transducers, and thrust chamber assembly servo-actuator position indicators at the equipment functional check, subsystem and system test levels.
 - d. Measuring external leakage of the assembled subsystems.
 - e. Functionally testing pressure regulators, check valves, relief valves and thrust chamber assemblies in the assembled subsystem using the OSE test connectors.
- 5.10.3 <u>Physical Characteristics</u> Physical characteristics of the propulsion subsystem test equipment are as follows:

Propulsion Subsystem Test Console - The console is mobile (caster mounted) and self-contained, consisting of 2 separate functional units (pneumatic and electrical). The pneumatic unit (contained in 2 cabinets) consists of pressure gages, pressure regulators, flow meters and hand valves for controlling and monitoring fluid test functions. Portable "bubbler" leak testers and leak test enclosures are provided to supplement the pneumatic section. The electrical bay (contained in 3 cabinets) consists of a power supply, programmer, strip recorder, analog displays, discrete displays, events indicators and switches for controlling and monitoring electronic/electrical test functions. Storage space for the "bubbler" testers, test

enclosures, cables, hoses and adapters required for operation are provided in the unit. The console is shown in Figure 5.10.1.

Helium Leakage Detector - The unit is mobile (caster mounted) and self-contained. The detector consists of a standard helium mass spectrometer leak detector (helium sniffer) detector probe, vacuum pump, calibrated leaks and a vacuum pump cold trap. Storage space for the detector probe, calibrated leaks and interconnecting hoses and cables is provided in the detector cabinet. The detector is shown in Figure 5.10-2.

5.10.4 Operational Description - Operation of elements of the propulsion subsystem test equipment, functionally shown in Figure 5.10-3, is as follows:

Propulsion Subsystem Test Console - Component external leakage is measured by pressurizing the component with gas while in the leakage test enclosure and measuring pressurant flow out of the enclosure (component leakage) with a "bubble" leakage tester. Component internal leakage is obtained by pressurizing the component with gas and measuring flow through the unit with a "bubbler" leakage tester. Pressure regulator lock-up, control range and response is tested by varying and monitoring up-stream pressure while measuring down stream pressure at zero flow through full flow. Relief valve cracking and reseat is checked by pressurizing the component and measuring the pressure at which the valve opens and reseats. Flow measurements are made with a "bubble" unit. Pressure transducer calibration is performed by supplying a variable pressure to the component while applying electrical excitation and measuring the response on a meter. RCS thrust chamber (TCA) assemblies are tested for flow and valve response. Flow is measured with a flow meter by pressurizing the TCA with isopropanol or helium gas and opening the valve electrically. Valve response is determined by a high speed oscillograph recording of the current "signature" of the valve coil. TPS TCA's are tested in a similar manner. Valve simultaneity is checked by parallel recording of both oxidizer and fuel valve current signatures. Fuel mixture ratio and throttling is tested by pressurizing the fuel flow control valve with isopropanol and the oxidizer flow control valve with freon MF and measuring flow through both loops. At the same time, throttle valve servo actuator position instrumentation calibration is checked against thrust level by correlating flow rate to thrust level.

Helium Leakage Detector - Subsystem external leakage is measured by pressurizing the subsystem with helium and searching the plumbing and components for leakage with the hand held helium detector probe. This method has proven successful on other low leakage brazed and welded systems. Canister leakage rate is obtained

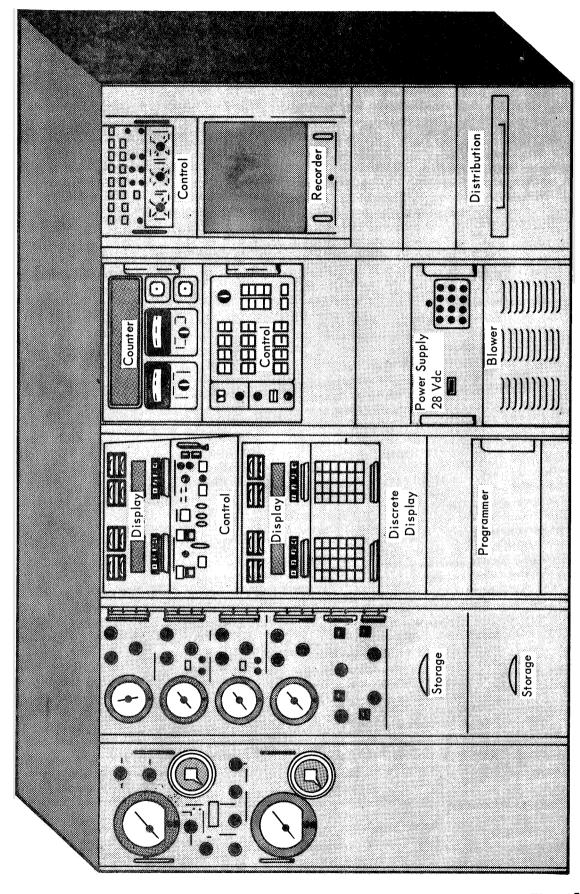


Figure **5.10–1**

HELIUM LEAKAGE DETECTOR

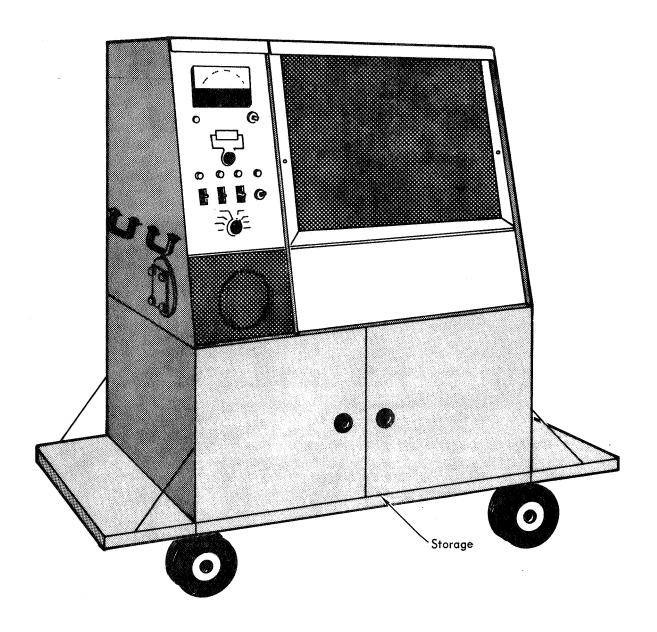
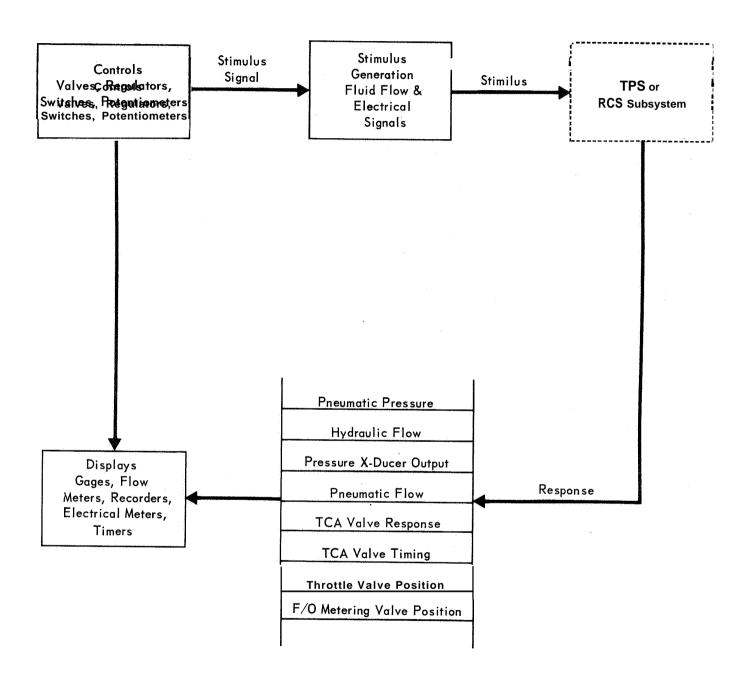


Figure **5.10–2**

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PROPULSION SSTS BLOCK DIAGRAM



by pressurizing the canister interior while in its shipping container and measuring the rise of helium concentration in the container.

- 5.10.5 <u>Performance Characteristics</u> The following is applicable to the design and function of the equipment:
 - o Fault isolation to the lowest replaceable part, component or module.
 - o Detection of leakage rates greater than 5.0×10^{-5} sec/sec.
 - o Measuring all functions to + 1% f nominal value.
 - o Indicating valve response and simultaneity to + 5 milliseconds.
- 5.10.6 <u>Interface Definition</u> The following interfaces are required in addition to the flight subsystem test connectors and fittings:

Propulsion Subsystem Test Console - Interfaces with facility power, GHe Pressurization Unit, freon MF and isopropanol supply units.

Helium Leakage Detector - Interfaces with facility power, GHe Pressurization Unit and the Canister Pressurization Unit.

- 5.11 AUTOMATIC PROCESSOR A brief description of the automatic processor selected to provide automatic test sequencing and monitoring for subsystem test sets is provided in this paragraph.
- 5.11.1 Equipment Identification and Usage Automatic test sequencing control, measurement and data recording is provided for selected subsystem test sets by the automatic processor a small, rack mounted, general purpose digital computer and its peripheral equipment. Incorporating automatic test and checkout features in selected SSTS results in test schedule flexibility, independent and/or simultaneous test set operation, minimum flight equipment operating time for tests and operator-induced errors, and maximum test repeatability. These factors contribute significantly to the probability of mission success of the flight subsystems by providing accurate, thorough and consistent test data. The automatic processor selected is identical in each test set to simplify programming, operation, maintenance and minimize total costs.
- Design Requirements and Constraints The quality of subsystem test data is of prime importance in the Capsule Bus program due to the loss of direct accessibility to the flight equipment after the sterilization canister has been installed. As a result, it is imperative that an adequate data bank or log be established which can be used during test operations for operating, anomaly, trend, and failure analyses and to assist in decision-making during systems tests through launch. To be meaningful for analysis, the data must be accurate, consistent (test repeatability), adequate in amount and depth, and must be available in

useable format. These requirements, including costs, are summarized in the trade study of Section 9 which indicates that the optimum solution is test automation by incorporation of an automatic processor in selected test sets.

In addition, the following operational constraints are adequately provided for with the implementation of the selected SSTS automation approach.

The SSTS is capable of:

- o interfacing with a general purpose digital computer for test sequence control, data gathering, and display. The individual SSTS automatic processor performs the detail test routines, fault isolation sub-routines, and data gathering. It also provides the potential for future operation in a "satellite" mode under the direction of a central computer, with a significant reduction in the programming complexity and memory capacity of the central computer.
- o performing all tests accurately, expeditiously and repeatably.
- o providing self-test capability without test interruption for isolation of problems to OSE or related capsule subsystem. Self-tests and calibrations are incorporated into the test program at strategic points to validate test data and isolate malfunctions without adding significantly to the test time.
- 5.11.3 Physical Characteristics The automatic processor, teletypewriter paper-tape punch/reader and peripheral equipment are mounted in a special cabinet to permit sitdown operation. The control panel is mounted in a standard cabinet along with its associated logic and interface. An example of a candidate off-the-shelf processor with adequate speed and memory to meet the subsystem test set requirements is the Digital Equipment Corporation's Model PDP-8/S, pictured in Figure 5.11-1.
- 5.11.4 <u>Performance Characteristics</u> Significant Performance characteristics are summarized below:
 - o control the application of stimuli to the subsystem under test.
 - o measure and compare subsystem responses to specified tolerance values.
 - o output out-of-tolerance data to the hard-copy printer.
 - o output all test data to the paper tape punch for recording.
 - o permit program input and modification by punched tape reader or teletypewriter.
 - o program SSTS self-test, calibration and diagnostic subroutines as a part of the normal test routine or "on demand",

AUTOMATIC PROCESSOR WITH CONTROL PANEL

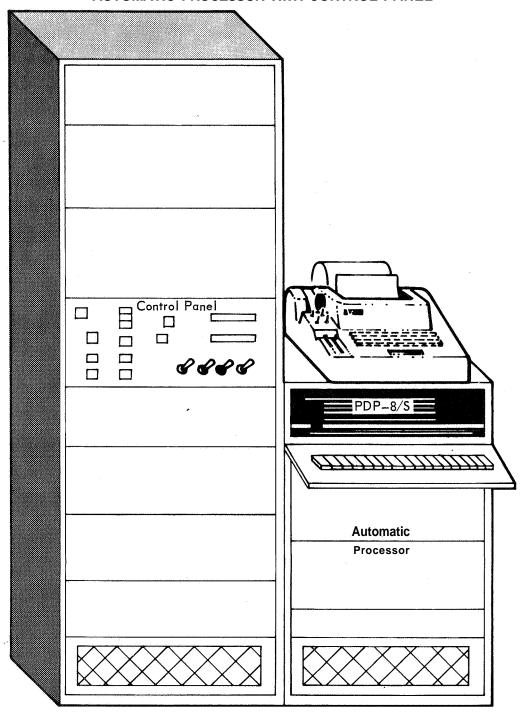


Figure 5.11-1

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- o Allow for manual override at any time.
- o prevent equipment damage, both to the OSE and flight subsystem, by driving to a safe condition in the event of a critical malfunction.

Software - Software for the SSTS is developed as a part of the software program as described in Section 8, Part D. The programming language is common to all SSTS which are automated to reduce costs and provide compatibility for all processors. Program de-bugging will be accomplished during the early development program phases utilizing the developmental models of the flight hardware.

Operational Parameters - Typical operational parameters required by the automatic processor are summarized below.

PARAMETER	SPECIFICATION
Memory Size	4k words, expandable to 32k words; (8k word memory considered adequate)
Word Size	12 bits, minimum
Memory Cycle	8.0 microseconds
Execution Speed	
Load word	\leq 40 microseconds
Store word	< 40 microseconds
Add	50 microseconds
Multiply, Divide (by subroutine)	~ 10 milliseconds
Priority Interrupt	Yes
Power Failure Protection	Yes
Compiler	Basic Fortran/Fortran II/IV
Index Registers	≥8 (memory)

- 5.12 MISCELLANEOUS SUBSYSTEMS TEST FUNCTIONS Test functions, in addition to those provided for by the subsystem-level test equipment, are required by the Capsule Bus and associated subsystems. Test requirements for these subsystems are identified and the means of testing indicated below.
- Canister and Adapter Subsystems Several Capsule Bus subsystems are physically located in the Canister and Adapter. These subsystems are supported for test and checkout by the corresponding CB subsystem test equipment as shown below:

Canister. and Adapter Subsystems	Supported by CB Support Equipment
Power	Electrical Power SSTS
Pressurization and Venting	Canister Pressurization Unit (AHSE)
Pyrotechnic	Pyrotechnic SSTS

Canister and Adapter Subsystems

Supported by CB Support Equipment

Sequencer

Sequencer SSTS

Te lemetry

Telecommunications SSTS

Thermal Control

Thermal Control SSTS

Each of the subsystems is subjected to an equipment functional check prior to its installation into the Canister or Adapter. Subsystem-level tests are performed during major module buildup and integration with the use of the support equipment noted above. Following mating of the Adapter, Canister and Capsule Bus, system tests are performed using STC equipment. Use of the Capsule Bus SSTS and AHSE permits a reduction in the quantity of test equipment required for flight subsystem operational verification.

- 5.12.2 <u>Cabling Subsystem</u> Complete checkout of the cabling is accomplished following fabrication and installation in the Capsule Bus, using factory test equipment. Continuity, hi-pot and grounding tests are performed as part of the factory tests for quality assurance. A functional check of the Cabling subsystem is made as the Capsule Bus subsystems are integrated in the system. Thus, no operational support equipment is required for factory tests of the flight system's electrical cabling.
- 5.12.3 <u>De-orbit Propulsion Subsystems</u> The de-orbit propulsion subsystem is a solid-propellant device, and by itself requires no OSE other than alignment equipment described in Section 6, Part D. Associated Electrical Functions pyrotechnic initiation and timing are tested by the Sequencer and Pyrotechnic Subsystem Test Sets.
- 5.12.4 <u>Aerodynamic Decelerator Subsystem</u> Electrically initiated pyro devices for the deployment of the decelerator are checked thoroughly by the Pyrotechnic Subsystem Test Set. No additional electrical tests are required.

SECTION 6

ASSEMBLY, HANDLING, SHIPPING (AHSE) AND SERVICING EQUIPMENT

- 6.1 AHSE Capsule Bus AHSE consists of the equipment required to assemble, service, checkout, weigh, balance, align and ship the Capsule Bus System and components from factory through Capsule/Spacecraft integration.
- 6.1.1 <u>Categories</u> AHSE is classified in accordance with functional and operational characteristics as follows.
 - a. Assembly and Handling Equipment utilized for capsule/component positioning and support, physical access to flight vehicles, component protection, and intrafacility mobility.
 - b. Mechanical. Testing and Rigging Equipment utilized for testing and rigging mechanical devices, and alignment of flight equipment.
 - c. Shipping Equipment utilized for interfacility mobility, and to provide physical and environmental protection of equipment in transit.
- 6.1.2 <u>Functional Requirements</u> Ground operations require equipment with the following capabilities:
 - a. Firmly retain Capsule Bus and aft canister with "z" axes horizontal to provide optimum accessibility and minimum impedance to laminar downflow
 - b. Hoist, position and support the Capsule Bus, Lander, De-orbit Motor and Parachute Assembly for assembly, service, checkout, installation and Capsule/Spacecraft integration.
 - c. Position, retain and interface both canistered and uncanistered capsules, Lander and De-orbit Motor with weight and balance fixtures.
 - d. Insert Lander, De-orbit Motor and Parachute Assembly laterally into the capsule
 - e. Provide mobility for flight equipment within facilities
 - f. Ship flight equipment from contractor's facility to KSC and remote test sites
 - a. Physically and environmentally protect equipment during shipment
 - h. Protect extendible elements during checkout and alignment
 - Rig and test mechanical devices and align items requiring critical positioning
 - j. Provide access to Capsule Bus and aft canister during ground operations
 - k. Protect both flight equipment and personnel from the hazards imposed by pyrotechnic and propellant handling, shock and vibration, static electric

discharge and possible mishandling

6.1.3 Design Criteria

General - Mobility will be in conformance with MIL-M-8090D. All AHSE/human interfaces will be in accordance with MIL-STD-803. That equipment utilized for air shipment of flight equipment, or which will itself be shipped by air will be designed in accordance with MIL-A-8421B. In addition, AHSE is designed to operate within the environmental constraints imposed by McDonnell Report E191, "Voyager Flight Capsule Equipments Environmental Specification."

<u>Safety</u> - AHSE utilized for physical handling operations will be designed to four (4) times static handling loads (items utilized for hoisting will be initially 'and periodically proof testing to two (2) times static handling loads). The following provisions will also be included in basic design considerations to eliminate hazards to both personnel and flight equipment:

- a. Positive locking devices for all load sustaining, movable components.
- b. Personnel protection will be provided by guard rails for upper platforms of work stands, covers for gear and cam assemblies and similar devices, and elimination of sharp or pointed projections.
- c. Lockable casters and provisions for securing large fixtures and work stands to the floor, and shock and vibration protection devices (e.g. shock mounts, springs, penumaric tires, etc.)
- d. Identification (placarding) of controls and devices potentially hazardous because of either an inherently critical operation or the damage resulting from mishandling.
- e. Equipment utilized for handling pyrotechnics, propellants, etc. will be statically grounded and fabricated of non-spark producing materials.
- f. Personnel interface points will be designed to eliminate the possibility of mishandling.

<u>Cleanliness</u> - The following criteria will be utilized in the basic design of AHSE utilized within Class 100 and 100,000 clean rooms:

- a. All external surfaces will be smoothly finished; and all seams and joints generously filleted.
- b. Pockets and horizontal surface areas created by structure or equipment which could trap dirt or stagnate air flow will be minimized.
- c. Surfaces which require lubrication will be "booted."
- d. Truss structures will be used when possible to minimize impedance to air flow.

<u>Maintainability</u> - AHSE will be designed to meet maintainability requirements through recognition of the following criteria:

- a. All parts or components subject to substantial wear or a reasonable possibility of damage shall be readily replaceable.
- b. Service ports, lubrication fittings, etc. will be easily accessible for servicing with standard equipment.

<u>Weight and Balance Equipment</u> - AHSE utilized for weight and c.g. determinations will provide:

- a. Minimum deflections under operational loads and minimim tare weights.
- b. Physical interface between flight equipment and weight and balance fixtures (e.g. facility provided pedestals, standard load cells and associated electronic equipment)
- c. Positioning for multi-axis orientation of flight equipment on weight and balance fixtures.
- 6.1.4 <u>Utilization</u> AHSE design must support the ground operations and tests defined in the Integrated Test Plan, Vol. VI. The functional flow of ground operations, and the use of AHSE, is illustrated in Figures 6.1-1 and 6.1-2.
- 6.1.5 <u>Functional Descriptions</u> The following major end items are described:

Capsule Bus Handling Fixture
Capsule/Canister Assembly and Checkout Stand
Flight Capsule Transporter
Air Transportation Adapter

Capsule Bus Adapter Fixture

Capsule Bus Handling Dolly

Forward Section Canister Stand

Capsule Bus Weight and Balance Adapter

Lander Installation Fixture

De-orbit Motor Installation Fixture
Capsule Bus/Aft Canister Work Stands
Capsule Bus Handling Sling
Canister Handling Sling
Forward Section Canister Sling
Lander and De-orbit Motor Handling
Fixtures
Auxiliary Hoist Control
Capsule Bus Mechanical Simulator

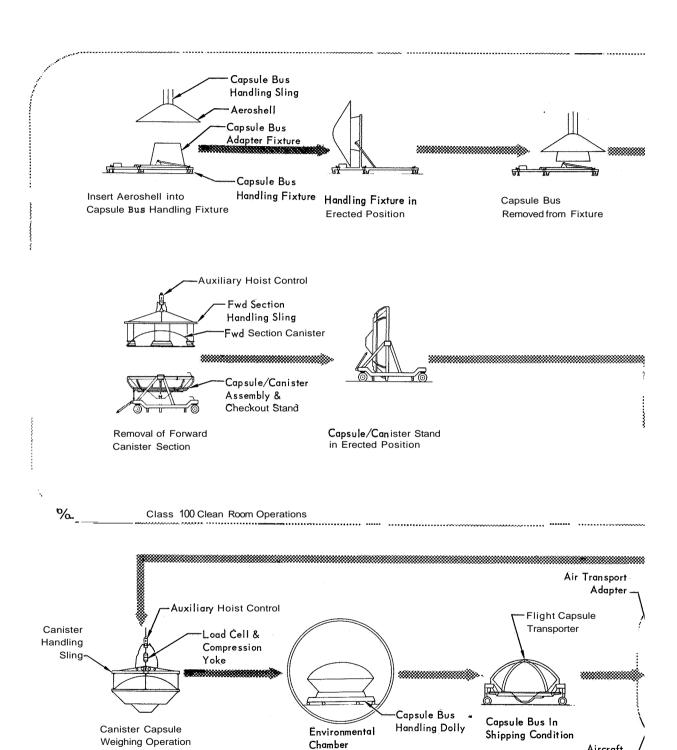
6.1.5.1 Capsule Bus Handling Fixture

<u>Usage</u> - The handling fixture, as shown in Figure 6.1-3, is designed to position and retain the Capsule Bus for assembly, service and checkout.

Design Requirements and Constraints - The general design of this fixture will be for use in a Class 100 clean room. It will also have provisions for limited intrafacility mobility and disassembly for shipment by common carrier.

<u>Physical Characteristics</u> - The basic elements of the fixture are: a rotation assembly (which interfaces with the Capsule Bus via the Capsule Bus Adapter Fixture), a trunnioned base assembly and an electro-mechanical drive assembly required for

CAPSULE BUS GROUND OPERATIONS AND AHSE, UTILIZATION AT CB CONTRACTOR'S PLANT

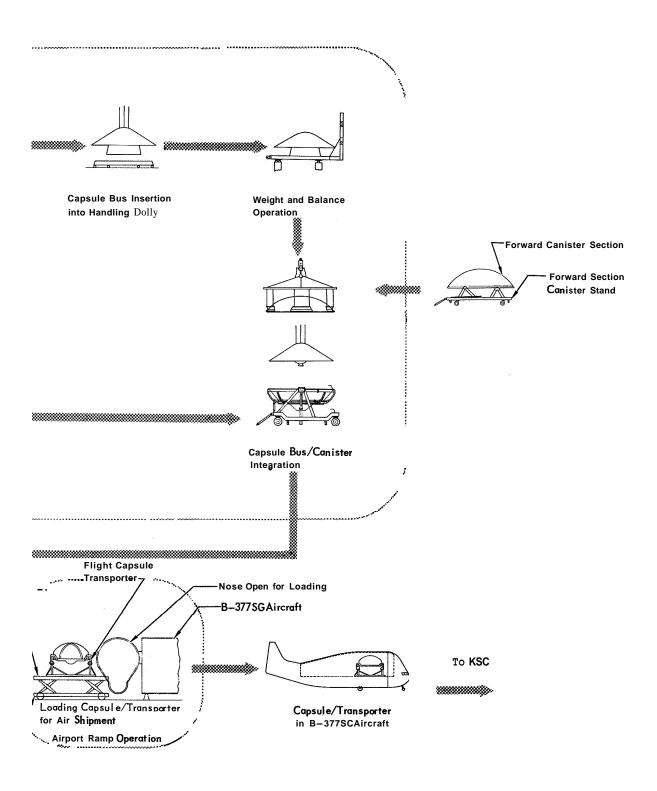


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Aircraft

Loader

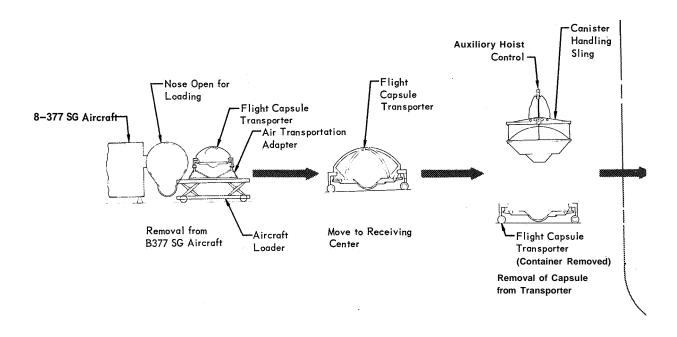
(Single Point)



jure 6.1-1



CAPSULE BUS GROUND OPERATIONS - KSC



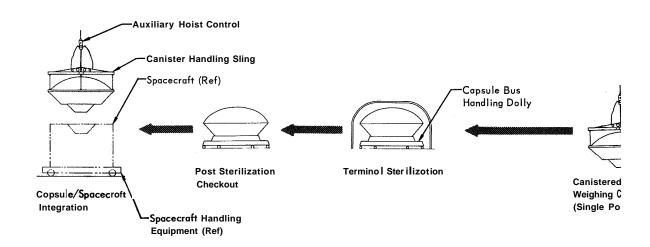
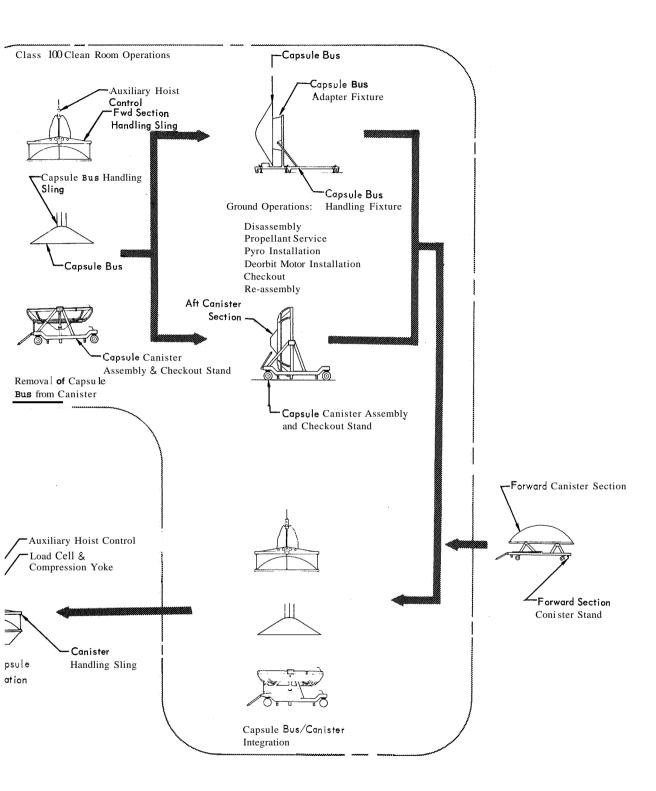


Figure 6.1-2

6-5-1



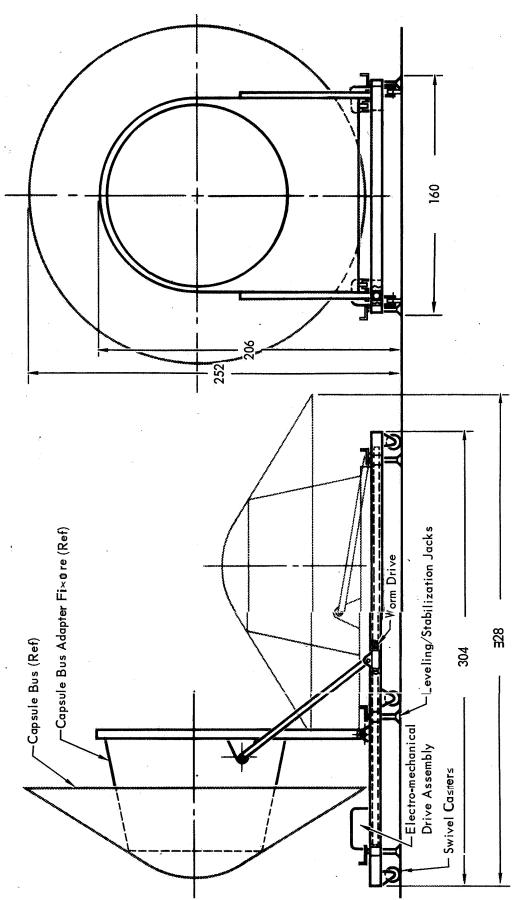


Figure 6.1-3

6-6

rotational power. A truss type structure of aluminum box beams is utilized throughout. Intrafacility mobility is afforded by lockable casters, and integral floor jacks are provided for anchoring the fixture to the floor during Capsule Bus rotation and subsequent operations. Provisions are included for interfacing with the installation fixtures required for the lateral insertion of the Lander, De-orbit Motor and Parachute Assembly. The rotation assembly also interfaces with the Capsule Bus Work Stand.

Operational Description - The aeroshell (or Capsule Bus during post assembly operations) and interfacing Capsule Bus Adapter Fixture are installed in the fixture while the rotation element is in a horizontal attitude. These items are then rotated 90°, and with the capsule "z" axis horizontal, the work stand and installation fixtures are installed. All subsequent assembly, service and checkout operations are accomplished with the fixture in this attitude.

Reliability and Safety Considerations — Since propellant servicing, and pyrotechnics and De-orbit Motor installation are accomplished while the Capsule Bus is retained in this fixture, provision for static electrical grounding is included. In addition, the electrical device used for rotation power is explosion proofed. Provision for positively locking the rotation element in the vertical position is provided to protect both flight equipment and personnel.

6.1.5.2 Capsule/Canister Assembly and Checkout Stand

<u>Usage</u> - This stand is used to retain and position the aft canister for assembly, service, checkout, insertion of the Capsule Bus and integration with the forward canister. It also provides limited intrafacility mobility for the aft canister and the canistered Capsule Bus.

<u>Design Requirements and Constraints</u> - The general configuration of this stand will be for Class 100 clean room operations, with the capability for intrafacility mobility. The capability for disassembly to allow shipment by a common carrier shall be included.

Physical Characteristics - This stand as shown in Figure 6.1-4 consists of a basic aluminum structural frame fabricated from rectangular shapes. Extending up from the frame are bearing trunnion supports holding the canister attachment interface frame. The interface frame is rotated about the tunnions by a motor driven gear reduction system. The interface frame has 360" rotational capabilities about the support assembly "z" axis. Locking of rotation about the trunnion is achieved by a spring loaded dog brake riding on the splined rotational shaft. Eight (8) cogs permit locking in 45° increments with ball lock pins. A removable support bar is

Figure 6.1-4

6-8

incorporated for rigidity. The basic frame is equipped with four (4) pneumatic tired caster wheel assemblies. Rigidity during stationary use is achieved with the screw jacks located at the corners. One end of the basic frame is open to permit positioning of the work platforms when the assembly is rotated. Both the screw jacks and the rotational locks are enclosed in flexible covers to eliminate clean room contamination. Extruded rubber shapes are used as mating flange protectors.

Operational Description - While suspended from its sling and an overhead hoist the canister is lowered into the attachment interface frame and oriented so the interface bolts can be secured. The canister is rotated about the "z" axis by release of the drop pins and operation of the turning motor controls.

6.1.5.3 Flight Capsule Transporter

<u>Usage</u> - This transporter is used to receive, support and protect the canister (or Flight Capsule) during shipment and storage. It is intended that the container be utilized at all times when the canister is not supported by other AHSE items.

<u>Design Requirements and Constraints</u> - The Transporter is designed in accordance with the following criteria:

- a. Compatibility with shipment by **B-377-SG** (Super Guppy) aircraft, barge, and helicopter (external).
- b. Towing speed shall not exceed 15 mph.
- c. Capability for handling by means of an overhead hoist and nylon web sling arrangement (for handling and transport by helicopter).
- d. Means to secure the container to the carrier.
- e. Ability to withstand a free fall from a height of 12 inches landing flat on its base.
- f. The suspension system mitigates dynamic transmitted loads to 5g axially and 1.25g radially with respect to the canister "z" axis.
- g. The design vibration input to the container is

<u>Frequency</u>	<u>Amplitude</u>
2 to 26 cps	±1.3g peak
26 to 52 cps	.036 inch double amplitude
52 to 500 cps	±5g peak

Such inputs are applied vertically through the container base only.

 h. The suspension system is designed to mitigate the transmitted vibration amplitudes to levels that will not result in damage to the Flight Capsule.

- i. Isolation of the canister from extremes of humidity, precipitation and blowing sand, dust, snow or hail.
- j. Maintaining a nitrogen atmosphere within the container with a delta pressure between the container and ambient of 1-2 psig.
- k. Design loads:

Positive Internal Pressure 5 psi
Canister (Flight Capsule) Weight 7000#
Overhead Handling 2g
Wind; Freely Standing 60 mph
Tied Down 100 mph

Helicopter 50 mph downward superimposed on 150

mph forward velocity

- 1. Design stresses are one-third the yield stress or one-fourth the ultimate stress if no yield stress is given.
- m. Provisions for controlling and guiding the Transporter by means of tag lines during handling.
- n. Provisions for stowage of the Transporter's own auxiliary equipment (slings, tow bars, special tools, etc.)
- o. Provisions for disassembly for shipment in a common carrier.
- p. Support of the canister at the canister/spacecraft interface ring with the "z" axis vertical.

Physical Characteristics of Operational Description - The Transporter fully encloses the Flight Capsule in a two-piece aluminum shell, as shown in Figure 6.1-5. The shell top half consists of a cylinder or prism approximately 254 inches in diameter with an approximately spherical dome (148 inch spherical radius). The top half of the shell disassembles into three sections for transportation empty. The base of the shell provides the interface for mating with the Canister/Spacecraft bus interface and generally conforms to the Canister shape aft of the Spacecraft bus interface. A gasketed closure is provided at the shell parting line. The shell base is, in turn, supported by a structural frame which, in some areas, is integral with the shell base, forming a container base assembly. The Transporter base assembly disassembles into sections suitable for conventional truck or air shipment. Intersecting arches pass over the top half of the shell attaching to the base assembly. The arches carry the loads experienced in hoisting operations and during transport by helicopter, and are used to handle the cover assembly. The interface between the arches and the shell top half prevents the transmission of structural

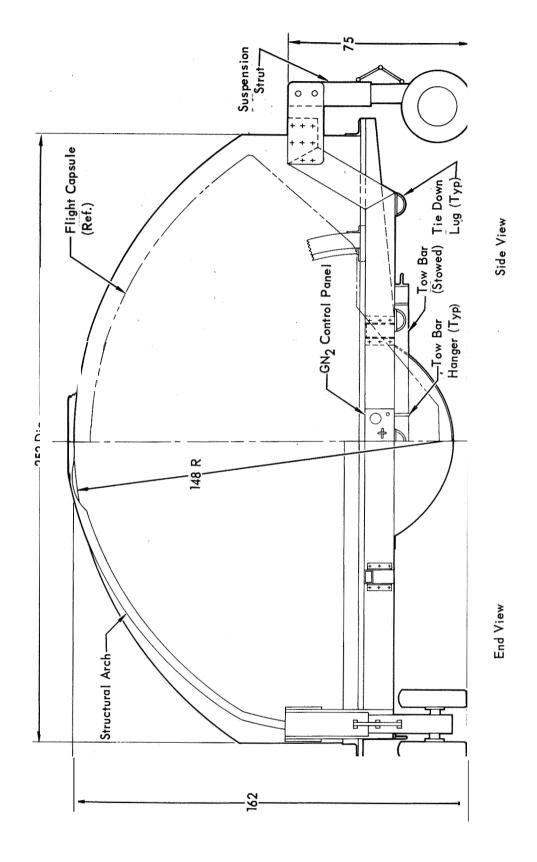


Figure 6.1-5 6-11

loads through the shell, thus providing capability for hoisting with simple sling, with minimum vertical hoist clearance. A nylon web sling, approximately 180 inches long, is provided for overhead hoisting and helicopter transport. Joints in the container shell are caulked to retain the GN2 atmosphere. Servicing connections and redundant relief valves are provided in the container base as is a GN2 supply for container replenishment and strut servicing. The suspension consists of four hydro-pneumatic struts at the corners of the base, affording shock and vibration protection to the canister. Mobility is provided by fully castered wheels which are part of the suspension strut assembly. Tow bar attachment and stowage provisions are included in the Container Base Assembly. Approximate overall dimensions are 300 in. long by 264 in. wide by 170 in. high. The Transporter weighs approximately 8000 pounds. Container proof loads are:

Positive Internal Pressure 10 psi Canister (Flight Capsule) Weight 14000.11 Overhead Handling 28000#

In view of the large container size required, the shell/structural arch configuration was selected as the most efficient and economical method for both capsule protection and container handling (hoisting).

6.1.5.4 Air Transportation Adapter

<u>Usage</u> - The Air Transportation Adapter is used to support the Canister Shipping Container within the B-377-SG (Super Guppy) aircraft, elevating the container so the maximum width is located approximately at the aircraft center line.

 $\underline{\text{Design Requirements and Constraints}} \ \ \overline{\ } \ \ \text{The adapter must satisfy the following}$ requirements:

- a. The adapter interfaces with the Guppy Pallet and with the base of the container.
- b. The design load for the Adapter is the loaded gross weight of the container.
- c. The Adapter is designed for handling by overhead hoist.
- d. The Adapter is designed to disassemble for return shipment by common carrier.
- e. Dynamic loads transmitted through the Adapter are 3g for 100 msec applied longitudinally and 1.5g for 100 msec applied laterally.
- f. The design vibration input to the Adapter is:

<u>Frequency</u>	<u>Amplitude</u>
2 to 26 cps	±1.3g peak
26 to 52 cps	.036 inch double amplitude
52 to 500 cps	±5g peak

This input is applied along vertical axis of the Adapter

Physical Characteristics and Operational Description - The Air Transportation Adapter as shown in Figure 6.1-6 raises the container approximately 80 inches within the Super Guppy Aircraft so that the container fits within the aircraft envelope. The Adapter consists of a framework of aluminum structural shapes that support the container at its running gear, and mounts on the Guppy Pallet. Fittings are provided for securing the Adapter and the container to each other and to the Guppy Pallet. Approximate overall dimensions are 300 inches long by 264 inches wide by 80 inches high; weight, 3000 pounds.

6.1.5.5 Capsule Bus Adapter Fixture

<u>Usage</u> - The adapter fixture provides a structural means for interfacing the Capsule Bus with Capsule Bus Handling Fixture, Handling Dolly and Weight and Balance Adapter.

Design Requirements and Constraints - Basic design requirements are:

- a. Sufficient strength to prevent excessive deflection during Capsule Bus weight and balance determinations.
- $^{ ext{b}}$. Minimum structure to provide a small tare weight.

<u>Physical Characteristics</u> — The fixture is of a truss type construction, with the general shape of a truncated cone. Both the top and bottom elements are rings which interface with the Capsule Bus at the flight adapter interface points and ground handling equipment respectively. Fabrication is largely of heavy gage aluminum tubing.

Operational Description - This fixture is utilized to provide the required support for the Capsule Bus during ground operations prior to its insertion into the aft canister.

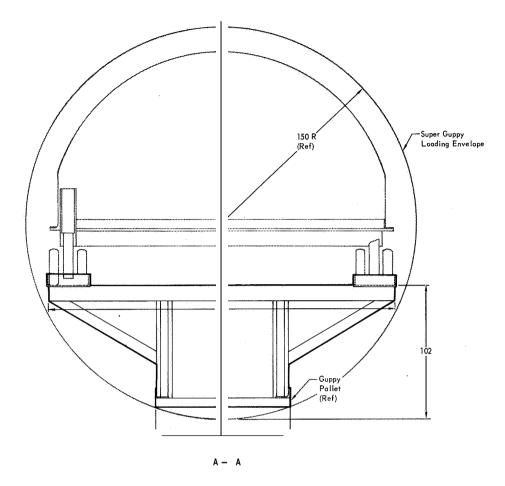
6.1.5.6 <u>Capsule Bus Handling Dolly</u>

<u>Usage</u> - The handling dolly provides intrafacility mobility for both canistered and uncanistered capsules. It is also used to insert and retain the capsule in the environmental chamber and sterilization oven.

Design Requirements and Constraints - General design and materials selection takes into consideration the temperature and size constraints imposed by use within the environmental chamber and sterilization oven.

<u>Physical Characteristics</u> — The dolly is a simple, welded steel platform provided with lockable casters for mobility. Provisions are included for interfacing with the sterilization canister (field joint) and the Capsule Bus Adapter Fixture. Tow bar fittings are also included as well as integral jacks for leveling and securing to the floor.

AIR TRANSPORT ADAPTER



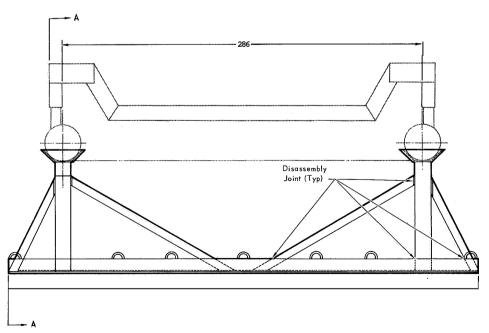


Figure 6.1–6 6–14

Operational Description - The capsule is inserted into the dolly with an overhead crane and hoisting sling. Mobility provisions allow towing of the capsule among the using sites within any facility over smooth and level surfaces.

Reliability and Safety Considerations - Shock mounts and rubber tired casters protect the capsule against shocks and vibrations incurred during intrafacility movement. Floor jacks allow firm retention to the floor during ground operations within environmental chamber and sterilization oven.

6.1.5.7 Forward Section Canister Stand

 $\underline{\text{Usage}}$ - This stand is used to hold, position and move the forward canister section within any facility.

<u>Design Requirements and Constraints</u> - The criteria outlined in this paragraph describes the requirements to which the stand is designed in order to achieve compliance with its use objectives. The criteria include:

- a. The design load for the stand is 500 pounds
- b. Rotational devices shall operate and support the design load with a maximum c.g. offset of 10 inches from the nominal location.
- c. All operating positions shall be capable of being retained by positive locking.
- d. Attachment of the canister section to the stand shall be at the field joint flange.
- e. The design constraints for Class 100 clean room equipment shall be followed.
- f. The stand shall be capable of disassembly for shipment by common carrier.

Physical Characteristics and Operational Description — This stand is presented in Figure 6.1-7 and consists of an aluminum base equipped with sprung pneumatic castered wheels providing mobility and extendable screw jacks for accomplishing the required rigidity. Attached to the base is an interfacing structure capable of pivoting to upright position. In use, the forward section is positioned over the interfacing frame that is configured to accept the section in a "z" axis vertical attitude.

Selective use of the field joint flange bolt pattern is used to bolt the section to the frame. When the section is rotated 90°, an overhead hoist is attached to the frame lift point and raised to pivot about its trunnions. When the correct attitude is achieved, the braces are installed and the hoist removed.

6.1.5.8 <u>Capsule Bus Weight and Balance Adapter</u>

<u>Usage</u> - The Weight and Balance Adapter is designed to position and support the Capsule Bus on the weight and balance fixture.

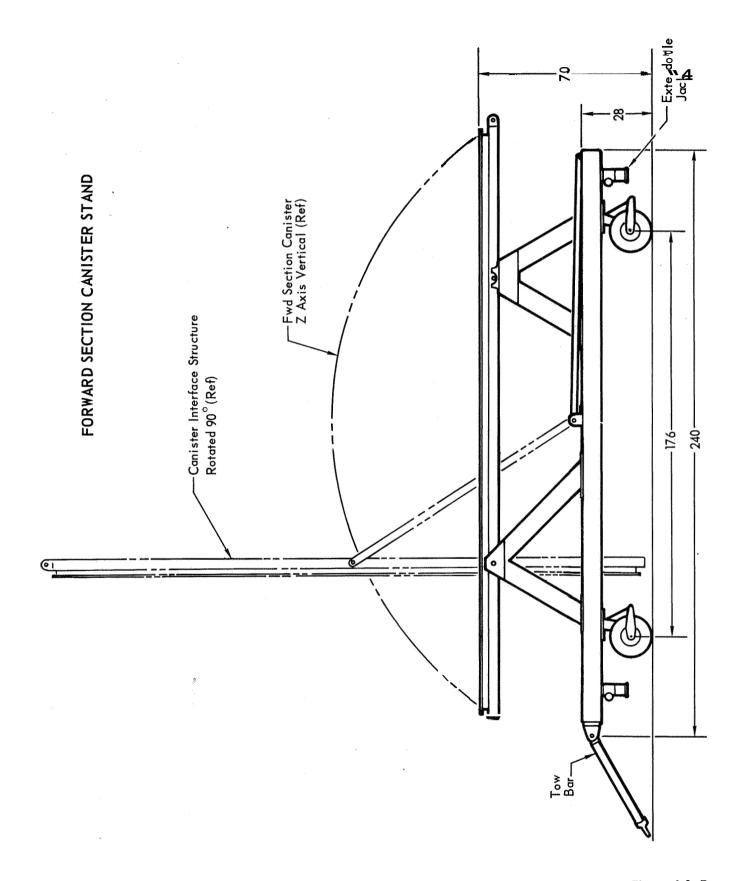


Figure 6.1-7 6-16

These fittings allow separate or coupled movement of the rails, thus providing the necessary vertical, horizontal and rotational alignment for installing the motor. The rails are provided with roller tracks to allow the motor to be moved manually.

Operational Description - Interfacing the installation fixture with the Capsule Bus Handling Fixture is accomplished while the Capsule is positioned with the "z" axis horizontal. The De-orbit Motor/handling cradle is lowered onto the rails by overhead crane. The De-orbit Motor is then manually pushed along the rails to its mounting points and the cradle removed. During this operation the motor is positioned by adjustment to the rails.

Reliability and Safety Consideration - The fixture is fabricated largely of aluminum (all materials will be non-spark producing) because of the hazards imposed in handling the De-orbit Motor. The rails are also provided with stops to prevent the inadvertent dropping of the motor from the rear of the fixture.

6.1.5.11 <u>Miscellaneous A H H - In keeping with the Phase B level of equipment definition</u>, the following functional descriptions are given in abbreviated form.

<u>Capsule Bus/Aft Canister Work Stand</u> - Welded pipe, truss structures with platforms designed to provide necessary access to Capsule Bus and aft canister during ground operations.

<u>Capsule Bus Handling Sling</u> - A hoisting device consisting of three steel cables and triangular spreader bar used for the insertion and removal of the Capsule Bus from the Capsule Bus Handling Fixture, the Weight and Balance Adapter and the aft canister.

<u>Canister Handling Sling</u> - This device consists of steel cables, spreader bar, and canister interface frame and is used for inserting the aft canister and flight capsule onto support stands and Flight Capsule Transporter, and for Capsule/Space-craft integration.

<u>Forward Section Canister Sling</u> - This sling is used to install and remove the forward canister section on the aft canister and Forward Section Canister Stand. It consists of steel cables, a spreader bar and a canister interface frame.

<u>Lander and De-orbit Motor Handling Fixtures</u> - Mobile structures designed to position and retain the flight items for assembly, service and checkout prior to installation.

<u>Auxiliary Hoist Control</u> - A standard Hydraset modified for Class 100 clean room operation which provides precise vertical control required during hoisting operations.

<u>Capsule Bus Mechanical Simulator</u> - A low cost, structurally reinforced shell constructed to canister dimensions and interfaces. It is internally weighted to

Flight Capsule weight and c,g, configuration, and is used for checking handling and transportation equipment clearances and interfaces at factory and KSC using sites.

Alignment Kit - A group of special gages, support fixtures, and associated optical tooling required for f,light equipment which must be critically aligned. This alignment equipment will be defined during Phase C. The flight equipment requiring alignment is:

<u>Item</u>	<u>Method</u>	<u>Operation</u>
Lander	optical	Capsule Bus final assembly
De-orbit Motor	optical	Capsule Bus Weight & Balance
VHF Antenna	mechanical	Capsule Bus final assembly
Radar antenna	mechanical	Lander final assembly
IMU	mechanical	Lander final assembly

- 6.2 SERVICING EQUIPMENT This section describes the equipment required to load and deservice the Terminal Propulsion Subsystem (TPS) and the Reaction Control Subsystem (RCS) with propellants and gases and to decontaminate and maintain these subsystems. In addition, equipment for propellant disposal, Sterilization Canister pressurization and gaseous pressurization for testing is included. Equipment utilization and approach rationale are described in addition to design requirements and criteria.
- 6.2.1 <u>Utilization</u> Use of the servicing equipment to support the Operations and Test Plan at the Capsule Bus (CB) contractor's plant and at KSC is shown in Figures 6.2-1 and 6.2-2 respectively. A summary of usage at the operational sites follows:

CB Contractor's Plant

- a. Component and module equipment functional testing
- b. Propulsion and canister subsystem functional testing on the subsystem level
- c. Propulsion and canister subsystem functional testing on the system level.

Kennedy Space Center

- d. Industrial Area system level testing
- e. Explosive safe facility system level testing, servicing and propellant disposal
- f. Launch Pad 39 propellant disposal and canister purge
- 6.2.2 <u>Categories</u> Servicing Equipment is classified in accordance with functional and operational characteristics as follows:

Loading Equipment - Used for conditioning and transferring liquids and gases into the capsule propulsion subsystem storage tanks, measuring and verifying the

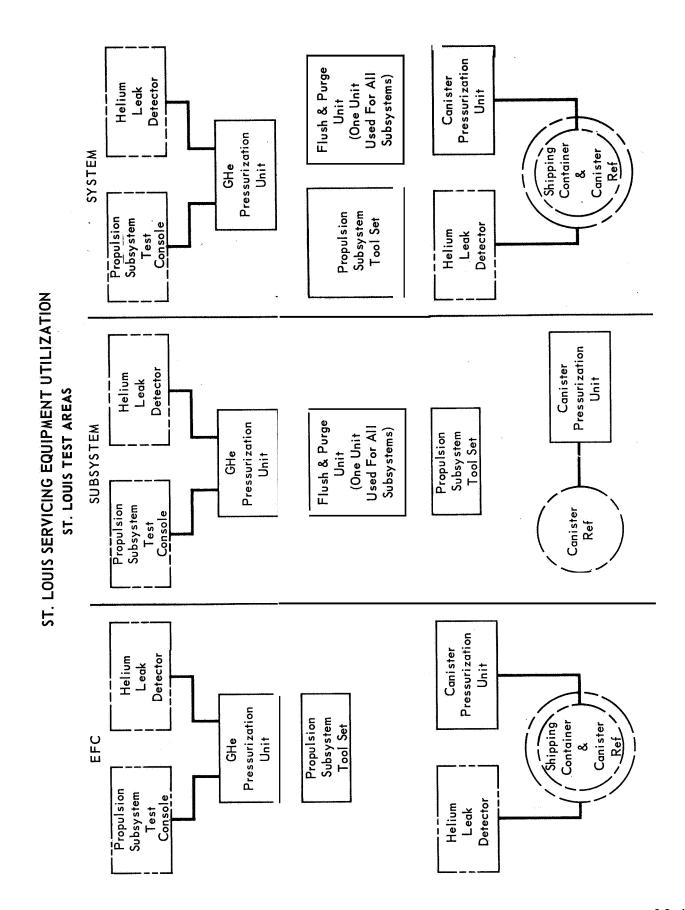


Figure 6.2-1 6-20

SERVICING EQUIPMENT UTILIZATION AT KSC

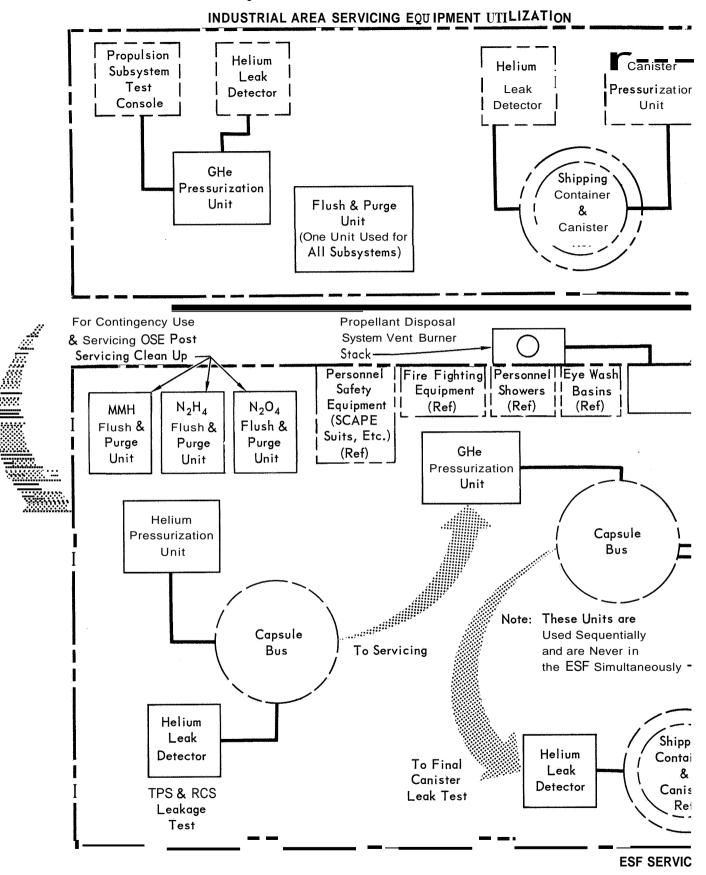
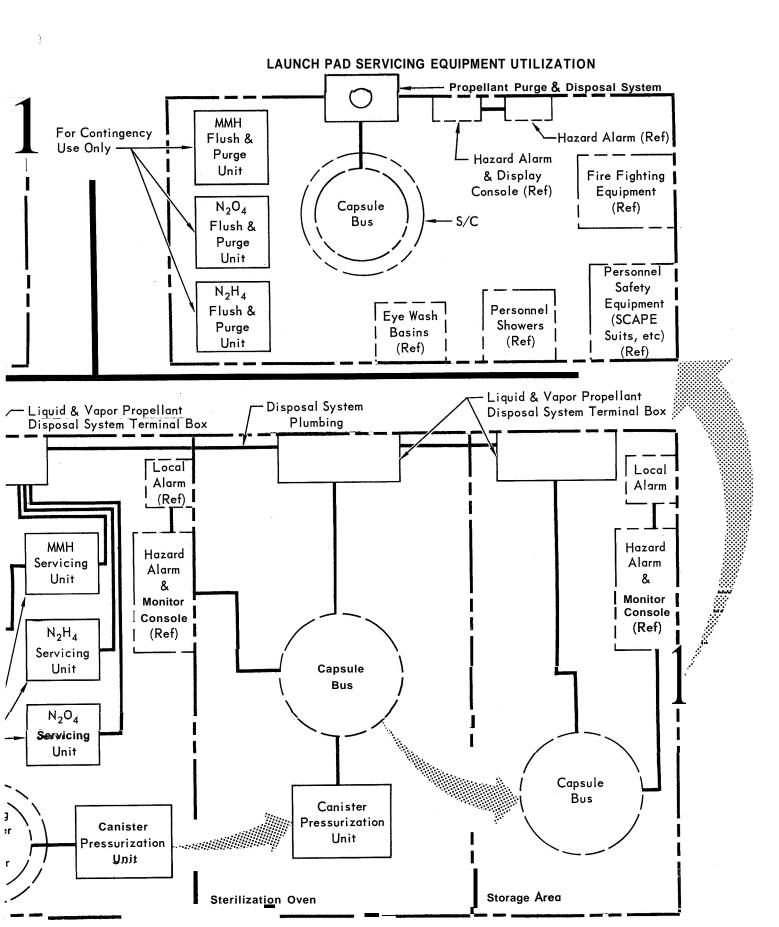


Figure **6.2–2**

6-21-1



IG EQUIPMENT UTILIZATION

quantity of liquids and gases transferred, and providing gases for subsystem testing,

<u>Decontamination, Cleaning and Maintenance Equipment</u> -Utilized for cleaning and decontaminating propulsion subsystems and loading OSE and supplying gases to maintain a positive pressure on the canister and capsule subsystems.

<u>Safety Equipment</u> - Utilized for preventing the build-up of a hazardous concentration of toxic or explosive liquids and vapors and disposing of toxic or hazardous fluids resulting from transfer operations. Providing an enclosure in which high pressure gas testing can be safely performed.

6.2.3 Requirements and Design Criteria -

<u>Function and Performance</u> - The Servicing Equipment provides the following capabilities:

- a. Load the TPS fuel tanks with Monomethylhydrazine (MMH)
- b. Load the TPS oxidizer tanks with Nitrogen Tetroxide (N_2O_4)
- c. Load the TPS pressure tank with helium (GH_{e})
- d. Load the RCS fuel tank with Hydrazine (N_2H_4)
- e. Load the RCS pressurant tank with nitrogen (GN2)
- f. Measure the quantity of fluids transferred to each tank
- g. Remove particulate contaminants and toxic fluids from both the capsule subsystems and loading OSE
- h. Maintain canister pressure within design limits during sterilization heating and cooling
- i. Maintain a positive gas pad on the canister during shipping and storage
- i. Provide gas for leakage and functional testing
- k. Dispose of toxic and explosive liquids and vapors
- 1. Display flight system parameters associated with the loading operations
- m. Protect both flight equipment and personnel from hazards resulting from high pressure gas and toxic and corrosive fluids.
- n. Detect propellant leakage in the canister following encapsulation
- o. Deservice the propellant tanks in the event of an emergency condition or propellant leak

6.2.4 Design

General - Mobility is assured by conformance with MIL-M-8090D, and equipment requiring air shipment is designed in accordance with MIL-A-8421. Equipment is designed to conform with the human engineering criteria defined in MIL-STD-803. Pressure vessels are designed to conform to ASME specifications and the propellant loading and disposal equipment electronics conforms to the applicable NEMA code.

The equipment is designed to operate within the environmental constraints imposed by McDonnell Report E191. All controls and displays are located on a central panel. Valves, regulators and gages comprising fluid circuit elements are located on a graphic panel schematic of the circuit. All hoses, pipes and tubing are identified per MIL-STD-1247. In addition, hose terminals are keyed to prevent inadvertent interface with the wrong fitting. Hoses and cables required for operation are supplied with the unit. Materials used in construction of the equipment are selected from the propellant compatible materials used in the Gemini propulsion servicing equipment.

<u>Safety</u> - All servicing equipment is provided with safety devices to preclude damage to flight systems or injury to operating personnel. These devices perform the following functions: Prevent unintentional overpressurization of the flight subsystems, positively vent all pressurized systems, protect against fire or explosion resulting from electrical sparking or arcing, and prevent accumulation of toxic concentrations of propellants.

Relief valves are used to limit pressures in all fluid lines. Relief valves and burst diaphrams protect pressure vessels and storage tanks. Pressure gages are supplied with safety blow-out disks. Hand valves are provided to bleed all pressurized lines and hoses. All equipment is designed to four times operating pressure and is proof tested to two times operating pressure.

<u>Cleanliness</u> - The following criteria were utilized in the design of servicing equipment: Use filters to preclude transfer of contaminants into the capsule subsystem, avoid dead ends, and voids that prevent proper cleaning of fluid circuits, and supply all connectors and fittings with caps to prevent the entry of contaminants.

Reliability - Reliability of servicing equipment is based on a conservative design approach and the use of proven components and equipment. Components are operated well below their maximum performance levels. MIBF selected is consistent with providing a conservative margin to support the scheduled servicing time lines and constraints. Design and assembly techniques, that contributed to the reliability of the Gemini hypergolic and gas servicing equipment are used. Specifically, welded and brazed joints are used to minimize leakage, GN₂ pressure transfer of propellants is used to eliminate pumps. Filters are used to protect system components and hand valves and hand loaded regulators are used to minimize complexity.

<u>Maintainability</u> - Servicing Equipment is designed for easy maintenance through use of the following criteria:

- a. All parts or components subject to substantial wear or the possibility of damage are readily accessible for replacement.
- b. Servicing ports, calibration fittings, etc., are readily accessible for servicing.
- c. The use of special tools and equipment for maintenance is held to a minimum.
- d. Filter elements are readily accessible for cleaning or replacement.
- e. En place gage calibration is provided.

6.2.5 <u>Functional Descriptions</u> - are provided for the following major items:

- a. GHe/GN₂ Servicing Unit
- b. N₂O₄ Servicing Unit
- c. MMH Servicing Unit
- d. N₂H₄ Servicing Unit
- e. Canister Pressurization Unit
- f. N₂0₄ Flush and Purge Unit
- g. MMH Flush and Purge Unit
- h. N₂H₄ Flush and Purge Unit
- i. Propulsion Subsystem Tool Set
- i. ESF Propellant Disposal System
- k. Launch Pad Propellant Disposal System

6.2.5.1 GHe/GN2 Servicing Unit

Identification and Usage - This unit provides a regulated supply of gaseous helium (GH_e) or nitrogen (GN₂) for TPS and RCS cold gas functional and leakage testing and servicing of the propellant pressurant tanks of both subsystems. The unit that is used at the CB contractor's factory and KSC is shown in Figure 6.2.3.

<u>Design Requirements and Constraints</u> - The unit is designed to meet the following requirements:

- a. Provide a 6000 psi, 3000 psi and 1000 psi regulated and instrumented $_{
 m GH_e}$ or $_{
 m GN_2}$ supply.
- b. Filter these supplies to 10 microns absolute.
- c. Provide pressure instrumentation accuracy of + 1% for the three pressure levels indicated.

<u>Physical Characteristics</u> - The unit is mobile (caster mounted) and self contained requiring only facility power for operation. Standard "K" bottles mounted on the unit are used to store the helium and nitrogen gas.

SERVICING UNIT - GHe/GN2 **Block Diagram** ▶ 0 - 1000 psi He Outlet GH_e Facility 0 - 3000 psi He Outlet Servicing Power Unit 0 - 6000 psi He Outlet Ambient Cooling Air 1000 Schematic 3000 2000 SW 3000 6000 Gas Manifold "K" Bottle-Storage -Control **Panel**

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Figure 6.2-3

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Operational Description - The unit is manually controlled. Gas flow is controlled with hand valves, and pressure levels are adjusted with hand loaded regulators. Pneumatic pressure gages indicate the pressure at each outlet. A boost pump is used to raise the supply ("K" bottle) pressure to 6500 psi and charge an accumulator. TPS pressurant is GH_e and RCS is GN₂.

<u>Interface Definitions</u> - The unit interfaces with the SSTS Propulsion Subsystem Test Console, the TPS and RCS pressurant servicing ports, the TPS and RCS test ports and facility power.

6.2.5.2 N₂O₄ Servicing Unit

<u>Identification and Usage</u> This unit is used to store $N_2^{0}_{4}$ and service the oxidizer tank of the TPS at the Explosive Safe Facility (ESF). A block diagram, schematic and conceptual drawing are shown in Figure 6.2-4.

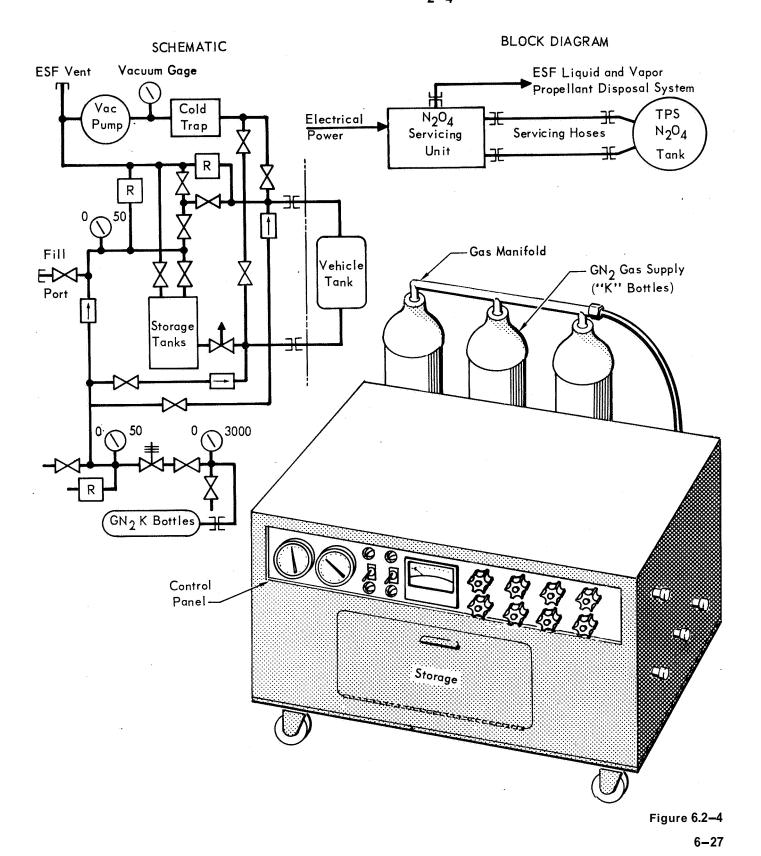
<u>Design Requirements</u> and <u>Constraints</u> The unit is designed to meet the following requirements:

- a. Storing sufficient quantities of $N_2^0_4$ to fill the TPS oxidizer tank
- b. Filtering the N_2O_4 to 10 microns absolute
- c. Transferring N_2^{0} to the TPS tank by nitrogen pressurization of the storage tank ullage space
- d. Measuring the quantity of oxidizer transferred to the TPS tank to
 ± 1% by weight of the TPS tank capacity
- e. Providing instrumentation to monitor TPS tank temperature, pressure and level indicators
- f. Deservicing the TPS tank
- f. Removing propellants from the transfer hoses prior to disconnection.

 Physical Characteristics The mobile unit (caster mounted) is self contained, requiring only facility power for operation. Standard "K" bottles, mounted on the unit, are used to store the GN₂ required for fluid transfer and inert gas padding. Load cells on the integral storage tank measure the weight of oxidizer in the tank.

Operational Description - The unit is manually operated. Fluid flow is controlled by hand valves and pressure levels are adjusted with hand regulators. Weight of oxidizer in the storage tank is displayed by a meter on the control panel, in addition to TPS tank pressure, temperature and level indicator lights. The quantity of oxidizer transferred is measured by weight and is displayed directly on the meter. A calibration of the TPS tank level indicators is obtained by

SERVICING UNIT - N204



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MCDONNELL ASTRONAUTICS

cross checking the level indicator display lights with the weight measurement display. Deservicing is achieved by pressurizing the TPS tank ullage with GN₂ and flowing the oxidizer back into the storage tank or the ESF Propellant Disposal System. Residual propellants are removed from the transfer hoses by evacuating them below the vapor pressure of the oxidizer. A cold trap prevents oxidizer vapors from entering the pump.

<u>Interface Definition</u> - The unit interfaces with the TPS fill and vent ports, the ESF propellant disposal system, and facility power.

Reliability and Safety Considerations - All electrical components are hermetically sealed or padded with GN₂ to prevent explosive vapors from entering the component (NEMA Code requirement). Toxic vapors can be removed from transfer hoses prior to disconnection and a cold trap prevents explosive vapors from entering the vacuum pump.

6.2.5.3 <u>Servicing Unit</u> - MMH

Identification and Usape - This unit is used to store MMH and service the fuel tank of the TPS at the ESF. The design of this unit is identical to the N_2O_4 Servicing Unit shown in Figure 6.2-4, except for minor material changes and the size of the storage tank.

6.2.5.4 Servicing Unit N_2H_4

Identification and Usage - This unit is used to store N_2H_4 and service the fuel tanks of the RCS at the ESF. A block diagram, schematic, and conceptual drawing are shown in Figure 6.2-5.

<u>Design Requirements and Constraints</u> - The unit is designed to meet the follow-ing requirements:

- a. Storing sufficient quantities of N2H4 to fill the RCS fuel tanks.
- b. Filtering the N₂H₄ to 10 microns absolute
- c. Transferring N_2H_4 to the RCS tanks by nitrogen pressurization of the storage tank ullage space.
- d. Measuring the quantity of fuel transferred to the RCS tanks to \pm 1%, by weight of the RCS tank quantity
- e. Providing instrumentation to monitor RCS tank temperature and pressure
- f. Deservicing the RCS tanks
- g. Removing propellants from the transfer hoses prior to disconnection
- h. Positioning the RCS tank bellows

Physical Characteristics - The mobile unit (caster mounted) is self contained requiring only facility power for operation. Standard "K" bottles, mounted on the unit, are used to store the GN required for liquid transfer and inert gas padding. Load cells on the integral storage tank measure the weight of fuel in the tank.

SERVICING UNIT - N2H4

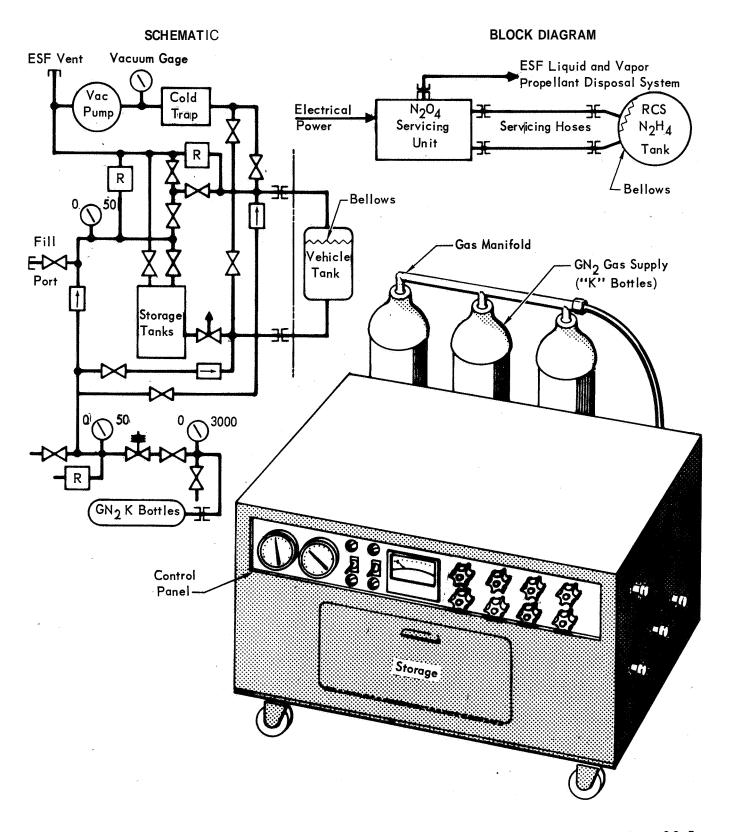


Figure **6.2–5**

6-29

Operational Description - The unit is manually operated. Fluid flow is controlled by hand valves, and pressure levels are adjusted with hand regulators. Weight of fuel in the storage tank is displayed by a meter on the control panel, in addition to RCS tank pressure and temperature. Tank bellows positioning is achieved either by pressurization or evacuation.

Deservicing is achieved by pressurizing the RCS tank bellows with ${\tt GN}_2$ thus blowing the fuel back into the storage tank or the ESF Propellant Disposal System. Residual propellants are removed from the transfer hoses by evacuating them below the fuel vapor pressure. A cold trap prevents fuel vapors from entering the pump.

<u>Interface Definition</u> - The unit interfaces with the RCS fill ports, bellows pressurization ports, ESF propellant disposal system, and facility power.

Reliability and Safety Considerations $\overline{}$ All electrical components are hermetically sealed or padded with GN_2 to prevent explosive vapors from entering the component (NEMA Code requirement). Toxic vapors can be removed from transfer hoses prior to disconnection and a cold trap prevents explosive vapors from entering the vacuum pump.

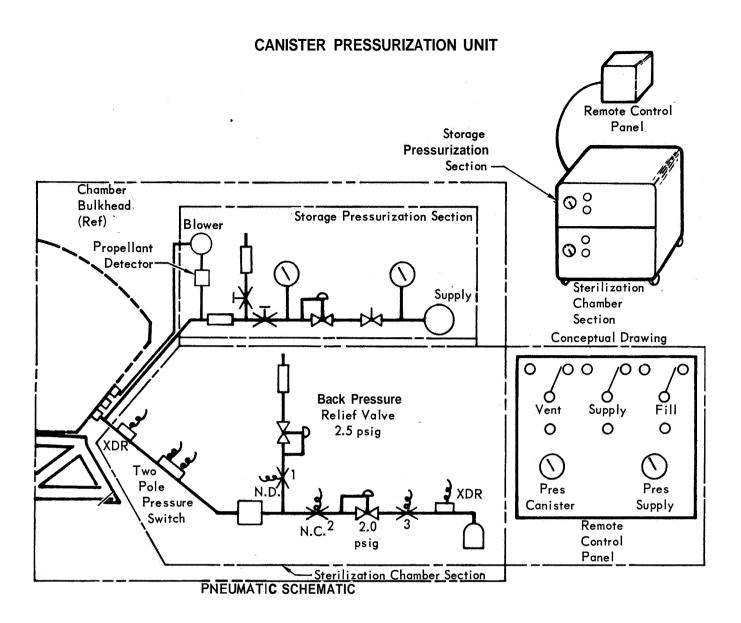
6.2.5.5 Canister Pressurization Unit

<u>Identification and Usage</u> - This unit provides gaseous pressurization and pressure control of the canister during leakage testing, sterilization, preflight storage, and during KSC operations. The unit is used at the factory and KSC. A schematic and conceptual drawing of the unit is shown in Figure 6.2-6.

<u>Design Requirements and Constraints</u> - The unit is designed to meet the following requirements:

- a. Purging the sealed canister with GN_2 to achieve a 97% \pm 1% N_2 atmosphere
- b. Injecting helium for leakage testing
- c. Venting the canister during sterilization heating when pressures exceed 2.5 psig
- d. Repressurizing the canister with sterile gas following heating to 2.0 psig
- e. Supplying 2.0 psig sterile make-up gas for canister leakage during storage, transit at KSC, and while on the launch pad.
- f. Detecting propellant leakage in the canister following encapsulation.
- g. Providing remote canister pressure control during sterilization
- h. Operating at sterilization temperature and following a sterilization cycle

 Physical 'Characteristics The unit is mobile (caster mounted) and self-contained requiring only facility power for operation. Tanks are provided to store



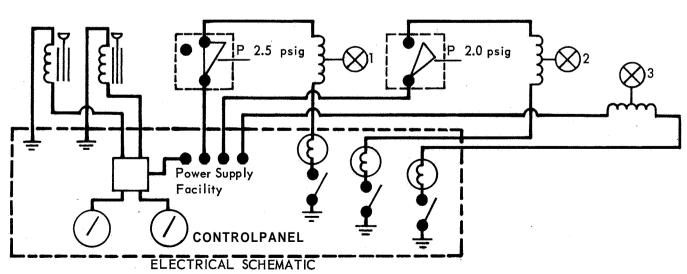


Figure **6.2–6**

the ${\rm GN}_2$ and ${\rm GHe}$ required for operation of the unit. Except for a remote control panel used during sterilization, all other valves, regulators, controls and displays are located on a central panel on the unit. The unit consists of a remote control panel, storage pressurization section and sterilization chamber section.

Operational Description - The unit is manually operated. Gas flow is controlled by hand valves and solenoid valves. Pressure levels are adjusted by hand regulators and back pressure relief valves. For leakage testing prior to sterilization the canister is purged with GN₂, GH_e is injected and leakage is detected with the SSTS Helium Leakage Detector. The unit is connected to the canister prior to sterilization and remains connected during heating. During heating, canister internal pressure is maintained at 2.5 psig by allowing gas to vent. Upon cooling, the canister pressure is maintained at 2.0 psig by the addition of sterile make-up gas from the unit. During storage, transportation and launch pad operations the unit remains connected to the canister to supply sterile make-up gas and sense CB propellant leakage.

<u>Interface Definition</u> - The system interfaces with the Hazard Alarm and Monitor System, canister vent and fill ports and facility power.

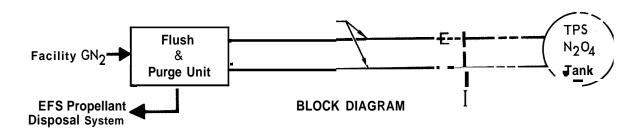
Reliability and Safety Considerations - The selected propellant detection system's reliability and performance were demonstrated on the Gemini propellant servicing system. All fluid joints in the storage pressurization system are brazed or otherwise sealed to achieve essentially zero leakage. The vapor detectors are capable of detecting propellant concentrations greater than 10 parts/million. 8.2.5.6 8.20_4 Flush and Purge Unit

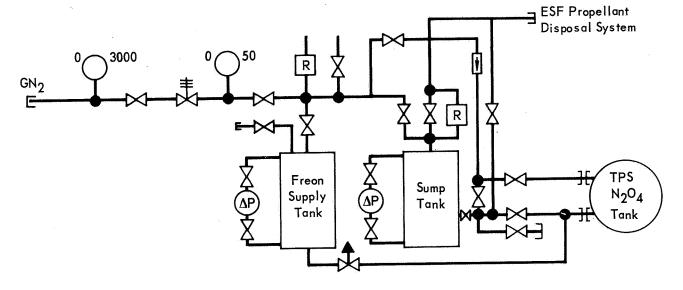
Identification and Usage - This unit is used to flush and purge a contaminated TPS oxidizer loop or associated loading equipment. The unit cleans and dries systems that are physically contaminated or contain toxic propellants. It is used both at the CB Contractor's factory and KSC. A block diagram, schematic and conceptual drawing of the unit are shown in Figure 6.2-7.

 $\underline{\text{Design Requirements and Constraints}} \ \hbox{--} \ \ \text{The unit is designed to meet the} \\ \text{following requirements:}$

- a. Storing sufficient quantities of freon MF to affect a complete flush of the TPS oxidizer loop or loading equipment.
- b. Storing sufficient quantities of ${\rm GN}_2$ to completely purge the TPS loop or loading equipment.
- c. Warming the ${\rm GN}_2$ to a temperature sufficient to vaporize freon.

FLUSH & PURGE UNIT N2O4





SCHEMATIC

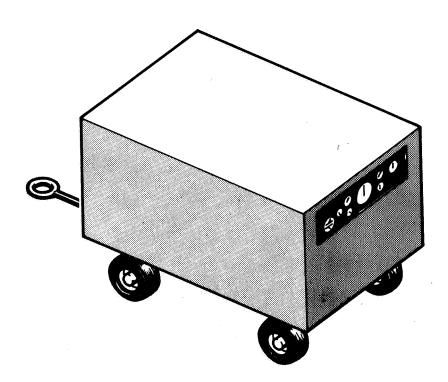


Figure 6.2-7

6-33

- d. Filtering the flush and purge fluids to 10 microns absolute.
- e. Storing contaminated flush fluid.
- f. Performing the flush and purge operation in a continuous closed loop cycle.

<u>Physical Characteristics</u> - The mobile (caster mounted) unit is self contained requiring only facility GN_2 and power for operation.

Operational Description - The unit is manually operated. Fluid flow is controlled by hand valves and pressure levels are controlled by hand loaded regulators. Flushing is accomplished by pressurizing the ullage space of the storage tank causing flushing fluid to flow through the contaminated system and back to the sump tank via hoses. Following the flush, the flight system is dried by flowing warn GN₂ through the system. The gas is warmed by an integral heater.

<u>Interface Definition</u> - Clean dry facility GN₂, electrical power and connection to the propellant disposal system is required. Particulate contamination of the facility GN₂ supply must not be greater than 25 microns absolute. Required dew point is -60°F minimum. The unit interfaces with the TPS oxidizer tank servicing ports and loading OSE hoses and terminal fittings.

Reliability and Safety Considerations - During operation, the Flush and Purge Unit is connected to disposal system to prevent inadvertent venting of toxic vapors.

6.2.5.7 MMH Flush and Purae Unit

Identification and Usage - This unit is used to flush and purge a contaminated TPS fuel loop or associated loading equipment. The design of this unit is identical to the N_20_4 Flush and Purge Unit, shown in Figure 6.2-7, except for minor material changes and the use of isopropanol as a flushing fluid.

6.2.5.8 N₂H₄ Flush and Purge Unit

Identification and Usage $\overline{}$ This unit is used to flush and purge a contaminated RCS fuel loop or associated loading equipment. The design of this unit is identical to the N₂0₄ Flush and Purge Unit, shown in Figure 6.2-7, except for minor material changes and the use of isopropanol as a flushing fluid. In addition, the flushing and purging is achieved by cycling the tank bellows rather than by flowing flushing fluis through the system.

6.2.5.9 Propulsion Subsystem Tool Set

<u>Identification and Usage</u> - These tools are used to maintain and perform mechanical operations on the TPS and RCS during test and maintenance operations.

The set is used at the CB Contractor's Factory and at KSC.

<u>Design Requirements and Constraints</u> - The set is designed to meet the following requirements:

- a. Opening and closing the RCS and TPS servicing and test ports and valves.
- b. Welding caps on valve actuating openings, servicing ports and test ports, following servicing
- c. Preventing sparks or temperatures which could cause fire or explosion.

<u>Physical-Characteristics</u> - The set consists of two major elements, a kit of hand tools supplied in a suitcase, and a mobile induction welding unit.

Operational Description - The set is manually operated. The hand tools fit the subsystem wrenching mechanisms to provide a method of opening and closing the valves. The welding unit provides the capability to weld the closure caps in place. All tools are made of non-sparking material. The welding tools are designed to localize heating to the cap area and to maintain EMI within specified levels.

Interface Definition - The set interfaces with facility power.

6.2.5.10 ESF Propellant Disposal System

Identification and Usage - This system, which is installed at the ESF, is used to dispose of propellant liquid and vapor resulting from a normal transfer operation, scheduled deservice, venting during sterilization or other propellant operations. The system also provides the capability to perform emergency deservice operations. A block diagram, schematic, and conceptual drawing are shown in Figure 6.2-8.

<u>Design Requirements and Constraints</u> - The system is designed to meet the following requirements:

- a. Collecting propellant liquid and vapor from the loading OSE, propulsion subsystems or from the Capsule Bus.
- b. Disposing of propellant liquid and vapor.
- c. Intentionally rupturing the flight subsystem canister membrane and rupture disks for emergency propellant deservicing.
- d. Purging the canister interior with inert gas in the event of a propellant leak.

<u>Physical Characteristics</u> - The system is permanently installed at the ESF and consists of fuel and oxidizer terminal boxes, vent stacks, vent burners, rupture system and gaseous purge system.

Operational Description - After initial start-up, propellant disposal is accomplished automatically. Propellants are introduced into the system at the terminal boxes where they are routed to the vent stack via interconnecting

ESF PROPELLANT DISPOSAL SYSTEM

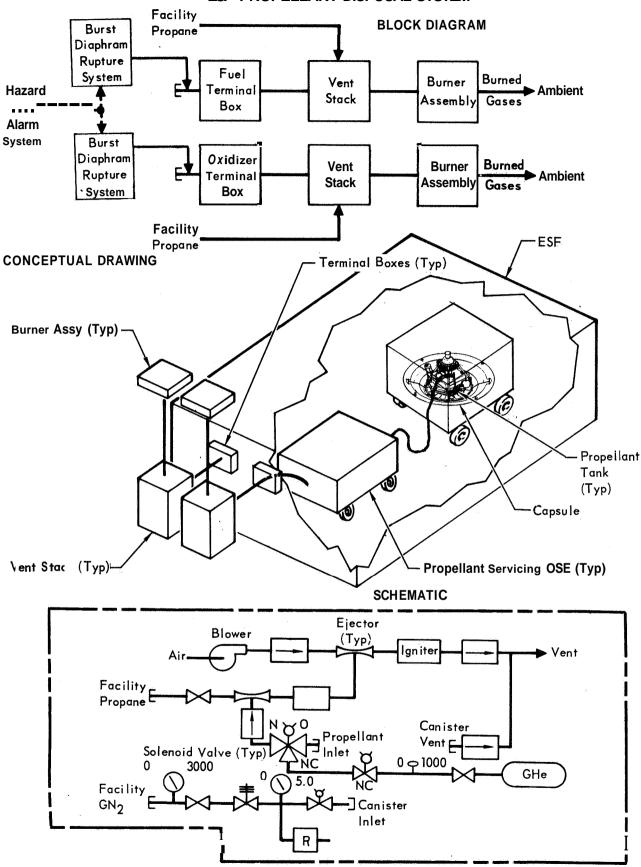


Figure **6.2-8**

6-36

plumbing. Pressure at the terminal boxes is subambient. In the vent stack they are mixed with propane and forced up, under a positive pressure, to the vent burners where incineration takes place. Burning is used as the disposal mechanism to positively eliminate the ejection of toxic contaminates into the air. The dump and purge sequence is accomplished automatically when a command is received from the Hazard Alarm and Monitor System. Gaseous helium directed to the canister overboard vent lines ruptures the canister membrane and propulsion subsystem burst discs, and pressurizes the propellant tanks. Three seconds later the propellants from the overboard vent lines are valved into the vent stack. From initiation to complete deservicing of the propellant tank requires about 15 seconds. GN₂ at the rate of 100 SCRM is automatically purged through the canister via flexible hoses.

Inteface Definition - The system interfaces with the following:

- a. Commands from the Hazard Alarm and Monitor System
- b. Connecting to the CB overboard vent lines and canister vent valve
- c. Facility GN₂, power and propane

6.2.5.11 Launch Pad Propellant Disposal System

Identification and Usage - This system is installed at launch pad 39, and is used for emergency propellant deservice, for purging the interior of the CB Canister, and for disposing of the waste propellants resulting from the deservice operation. A block diagram, schematic and conceptual drawing are shown in Figure 6.2-9.

<u>Design Requirements and Constraints</u> - The system is designed to meet the following requirements:

- a. Intentionally rupturing the flight subsystem Canister membrane and rupture discs for emergency propellant deservicing.
- b. Purging the Canister interior in the event of a propellant leak.
- c. Disposing of propellant liquid and vapor.

<u>Physical Characteristics</u> - The system is permanently installed at the launch pad and consists of fuel and oxidizer terminal boxes, vent stacks, vent burners, rupture system and gaseous purge system. Further study of the requirements for emergency deservice at the launch pad versus the associated interface penalties is required during Phase C.

<u>Operational Description</u> - Operation of this system is identical to the ESF Propellant Disposal System in the deservice and purge mode.

Interface Definition - To operate, the system must be connected to the CB at the launch pad. Two alternatives are available for making the connection

LAUNCH PAD PROPELLANT DISPOSAL SYSTEM

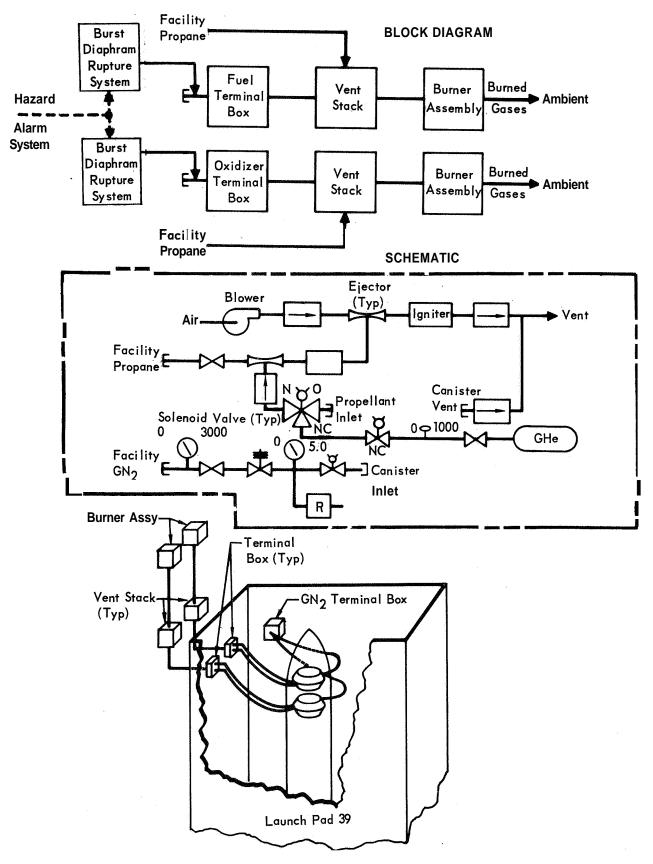


Figure *6.2-9*

The first approach requires a door in the PV shroud to provide access to the CB connectors. This approach provides deservice capabilities only until the Mobile Service Structure is moved away. The second method is to interface the system through a fly-away umbilical at the PV shroud mold line. This approach provides deservice capabilities up to lift off. In addition to the above, the following interfaces are required:

- a. Commands from the Hazard Alarm and Monitor System
- b.. Connecting to the CB overboard vent lines and the canister vent valves
- c. Facility power, GN₂ and facility propane

SECTION 7

SPACECRAFT-MOUNTED CAPSULE BUS SUPPORT EQUIPMENT OSE (SCME)

Four Capsule Bus support Telecommunications subsystems are physically located in the Spacecraft. Complete subsystem-level test capability for these subsystems is provided by the CB/SC TCM Subsystems Test Set (SSTS).

- 7.1 EQUIPMENT IDENTIFICATION AND USAGE The SSTS is used to acceptance test the following CB/SC TCM subsystems:
 - a. Support Radio
 - b. Support Data Storage
 - c. Flight Capsule Command Decoder
 - d. Support Telemetry Equipment

In addition, the equipment is used for compatibility and qualification testing of the CB/SC TCM subsystems, for flight capsule integration testing and functional testing at the Capsule Bus contractor's facility and at KSC for contingencies.

- 7.2 DESIGN REQUIREMENTS AND CONSTRAINTS The SSTS performs the following functions:
 - a. Provides two stable FSK-modulated UHF signals to test the support radio receivers and diversity combiner.
 - b. Provides simulated serial PCM data to verify performance of the command decoder and telemetry equipment.
 - c. Provides decommutation of the telemetry data from the flight capsule **M** data distribution unit at the 4, 7, 273, and 2730 bps data rates.
 - d. Interfaces with an automatic processor for automatic test sequencing. The equipments that accept external control in this mode are:
 - o Digital voltmeter input selector
 - o Counter input selector
 - o Telemetry controller
 - o Printer input selector
 - o Command generator
 - o CB/SC mode control
 - O Canister and Adapter TM generator
 - e. Provides print-out of the output data of the digital voltmeter, counter, telemetry decommutator and the automatic processor.
 - f. Provides a display unit to permit selectable channels of telemetry data to be viewed for a quick-look analysis.

- 7.3 PHYSICAL DESCRIPTION The CB/SC TCM Subsystems Test Set is housed in six standard electronic equipment cabinets as shown in Figure 7.3-1. The total weight of the test set is approximately 1500 pounds. AC power consumption is estimated to be 3700 watts.
- 7.4 OPERATIONAL DESCRIPTION The CB/SC TCM Subsystem Test Set provides manual or automatic checkout of the combined CB/SC TCM subsystems. This equipment also provides manual checkout of the individual CB/SC TCM subsystems. See functional block diagram, Figure 7.4-1.

In the automatic mode, the processor generates instructions from the test program and routes the instruction to the proper portion of the test set for execution. All portions of the test set which are automatic are also capable of manual control. The automatic processor also selects the source of the data for processor entry. Data is available from the digital voltmeter, counter, or telemetry processing equipment.

The CB/SC mode control panel, under manual or automatic direction, supplies the power and control stimuli necessary to exercise the combined CB/SC TCM subsystems in all of their operational modes. Control signals are supplied to the flight units via the direct access connectors.

The Canister and Adapter TM generators provide simulated data as inputs to the data distribution unit. This will be parallel data, variable over the limits of the various flight operational modes.

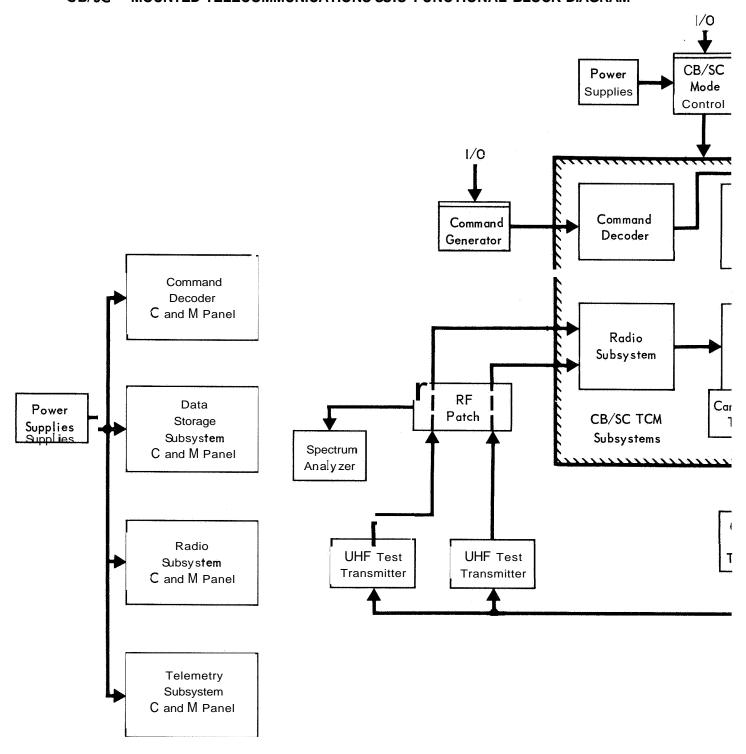
The command generator provides simulated command data to the command decoder. The generator is capable of manual or remote operation by the processor. In the manual mode, command comparison with the command decoder output is performed by logic in the command generator. In the automatic mode, command comparison is performed by the automatic processor.

Two UHF test transmitters are provided for simultaneous checkout of the two CB/SC receivers and the diversity combiner. The FSK modulation signal for driving the test transmitters is supplied by the telemetry signal simulator. Precision variable attenuators are supplied in the test transmitter to vary the RF input level to facilitate sensitivity and dynamic range measurements. A noise source is provided for injecting noise on the RF carrier. Also, a perturbation generator is supplied as part of the TM signal simulator to permit injection of noise, jitter, wow and baseline offset of the modulation signal.

					11.11			Automatic			
TM Signal	Simulation TM Signal Conditioner Frame	TM Signal	Data Distributor	N.	Controller	Printer Input Selector			i i	Power Supply	
AC Power Control	Data Patch Panel		ф 0 % 0 Д		Digital Voltmeter	DVM Input Selector	Counter	Counter Input	Selector	Power Supply	
	Wave Analyzer	Oscilloscope	RMS	Voltmeter	CB/SC Mode Control	Canister Canister and	Adapter TM		Command Generator	Power Supply	
AC Power Control	RF Patch	Panel			Spectrum Analyzer		UHF Test	Transmitter	UHF Test Transmitter		
	Intercom	<u>.</u>	Subsystem Control and Monitor	<u> </u>	Telemetry	Subsystem	Monitor Panel		Power Supplies	Power Supply	
AC Power Control	Data Storage Subsystem	Monitor Panel	Command Decoder	Control and	Monitor Panel				Power Supplies	Power Supply	

Figure **7.3**–1

CB/SC - MOUNTED TELECOMMUNICATIONS SSTS FUNCTIONAL BLOCK DIAGRAM

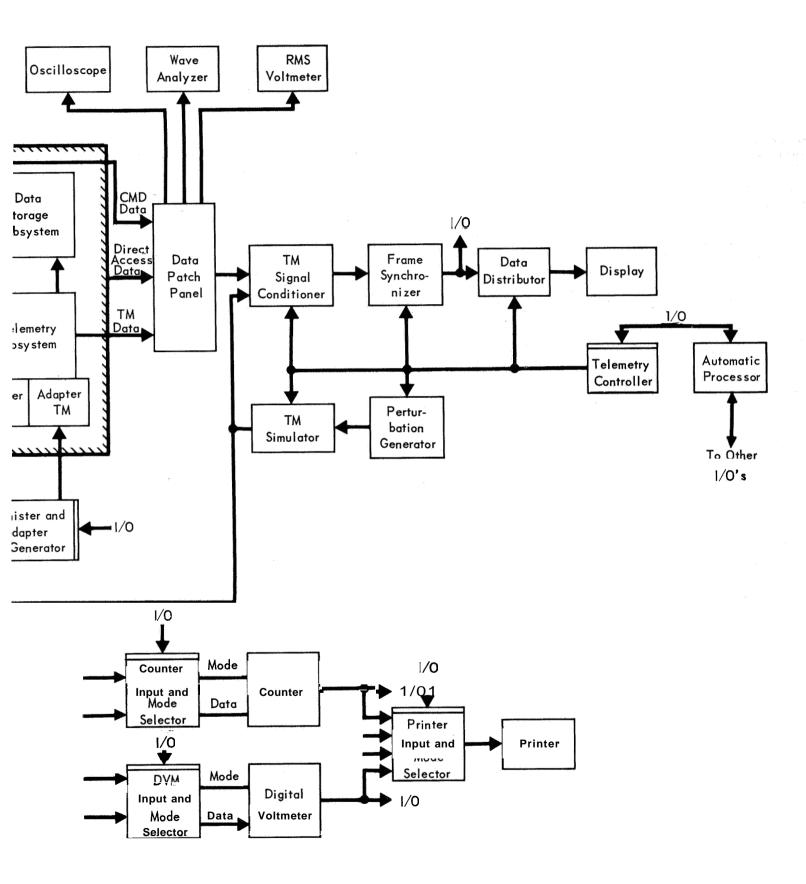


Notes:

I/O - Automatic Processor Input/Output C & M - Control & Monitor

Figure 7.4-1

7-4-1



The telemetry processing portion of the subsystems test set consists of the following:

- a. TM controller
- b. TM signal simulator
- c. TM signal conditioner
- d. Frame synchronizer
- e. Data distributor
- f. Perturbation generator

The TM controller is controlled by the automatic processor. This unit automatically sets up the proper bit rate, input code, polarity, detector type, phase-locked-loop width, capture and tracking range and output code of the TM signal simulator, the TM frame synchronizer, subframe synchronizers, the data distributor, and the TM signal conditioner. During the manual operating mode and in testing the individual TCM subsystems, the parameters are selected by manual switches on the individual equipment front panels.

The DVM input selector, counter input selector and printer input selector provide manual or automatic control of the data being supplied to the respective units. In the case of the DVM and counter, range and function are also controlled by the input selector. The printer prints out decommutated telemetry data during simulated cruise, in-flight checkout, de-orbit cruise, entry and landing phase modes. Data from the DVM, counter and from the processor can be printed out. Data print out is in real time.

Provisions are made for automatic or manual self-check of the OSE. Self-checks are performed without test interruption. The DVM and counter input selectors contain calibrated input positions. Calibration can be verified by the processor at the instrument output, by print-out on the printer, and/or by visual readout. The telemetry processing equipment can be checked by applying a known input from the PCM simulator and by checking the output on the printer, display unit or by the processor. A control and monitor panel is provided for each subsystem to provide power and test stimuli to the subsystem under test. Inputs to the subsystem are made to both flight and direct access connectors. Test requirements of the subsystems are detailed in Figures 7.4-2, 3, 4, and 5.

- 7.5 INTERFACES The CB/SC TCM SSTS interface with the spacecraft-mounted TCM subsystems as follows:
 - a. Individual Subsystems Testing During individual subsystems testing, the

- TCM SSTS interfaces with both the flight connectors and direct access connector of each subsystem. (See Figure 7.5-1)
- b. Combined Subsystem Testing During combined subsystem testing, the TCM SSTS interfaces with the direct access connectors of each subsystem and the flight connectors which interface with other than TCM subsystems. (See Figure 7.5-2).

SUPPORT RADIO SUBSYSTEM TEST REQUIREMENTS

TEST	MEASURING INSTRUMENT	ACCUI	RACY
Threshold Signal	Test Transmitter/Spectrum	1	db
	Analyzer		
AGC Voltage	Digital Voltmeter	2	%
Local Oscillator Frequency	Counter	1 x :	10 ⁻⁸
Mixer Current	Digital Voltmeter	5	%
Power Supply Voltage	Digital Voltmeter	0.1	%
DC Current Drain	Digital Voltmeter	5	%
Dynamic Range	Test Transmitter/Spectrum	1	db
	Analyzer		
Bandwidth	Test Transmitter/Spectrum	5	%
	Analyzer		
Image Rejection	Test Transmitter/Spectrum	1	db
	Analyzer		
Demodulation/Video Test	Scope/Wave Analyzer	5	%
RF Input Impedance	Network Analyzer	5	%
TM Monitors	Digital Voltmeter	2	%
Video Output Detector	Digital Voltmeter	2	%

Figure 7.4-2

FLIGHT CAPSULE COMMAND DECODER TEST REQUIREMENTS

	and the state of t	
TEST	MEASURING INSTRUMENT	ACCURACY
Power Supply Voltage	Digital Voltmeter	3 %
Power Supply Current	Digital Voltmeter	3 %
Input Command Data Word	Scope/Command Generator	Digital
Parity	Scope/Command Generator	Digital
Decoded Commands	Scope/Command Generator	Digital
Command Event	Scope/Command Generator	Digital
Bit Sync.	Scope/Command Generator	Digital

Figure 7.4-3

SUPPORT TELEMETRY SUBSYSTEM TEST REQUIREMENTS

TEST	MEASURING INSTRUMENT	ACCURACY
Data Distribution Unit		
Power Supply Voltage	Digital Voltmeter	3 %
Power Supply Current	Digital Voltmeter	3 %
Input Clocks	Scope/TM Signal Simulator	Digital
Output Clocks	Scope/TM Processing Equip.	Digital
Input Data	TM Data Connector	Digital
Output Data	Scope/TM Processing Equip.	Digital
Input Commands	Scope/Command Generator	Digital
Operating Sequence	Scope/TM Processing Equip.	Digital
Output Commands	Scope/TM Processing Equip.	Digital
Support Equipment Commutator		,
Power Supply Voltmeter	Digital Voltmeter	3 %
Power Supply Current	Digital Voltmeter	3 %
Input Clock	TM Signal Simulator	Digital
Commutation Sequence	Scope/TM Processing Equip.	Digital
Input Analog Signals	Digital Voltmeter	1 %
Data Output	Scope/TM Processing Equip.	Digital
Conversion Accuracy	TM Gen./TM Processing Equip.	1 %

SUPPORT DATA STORAGE SUBSYSTEM TEST REQUIREMENTS

TEST	MEASURING INSTRUMENT	ACCURACY
Input Data	Scope/TM Signal Simulator	Digital
Output Data	Scope/TM Processing Equip.	Digital
Memory "Overflow" Signal	Digital Voltmeter	2 %
Memory "Empty" Signal	Digital Voltmeter	2 %
Power Supply Voltage	Digital Voltmeter	2 %
Power Supply Current	Digital Voltmeter	2 %
Input Clock Frequency	Counter/TM Signal Simulator	Digital
Output Clock Frequency	Counter/TM Processing Equip.	Digital
Sequencing Clock Frequency	Scope/TM Processing Equip.	Digital
Tape Speed	Counter	1 %
Tape Direction	Digital Voltmeter	2 %
Tape Bias Voltage	Digital Voltmeter	2 %
Tape Motor Drive Voltage	Digital Voltmeter	2 %
Tape Motor Frequency	Counter	1 %
Tape Motor Phasing	Oscilloscope	3 %
Command Verification	Digital Voltmeter	2 %

CB/SC-MOUNTED TELECOMMUNICATIONS SSTS INTERFACE DIAGRAM (INDIVIDUAL SUBSYSTEMS TESTING)

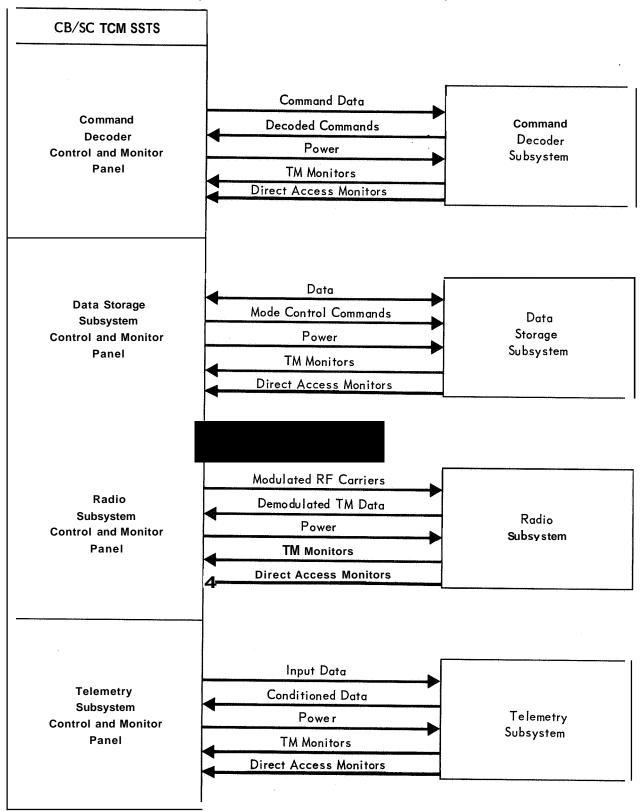


Figure 7.5-1

CB/SC -MOUNTED TELECOMMUNICATIONS SSTS INTERFACE DIAGRAM (COMBINED SUBSYSTEMS TESTING)

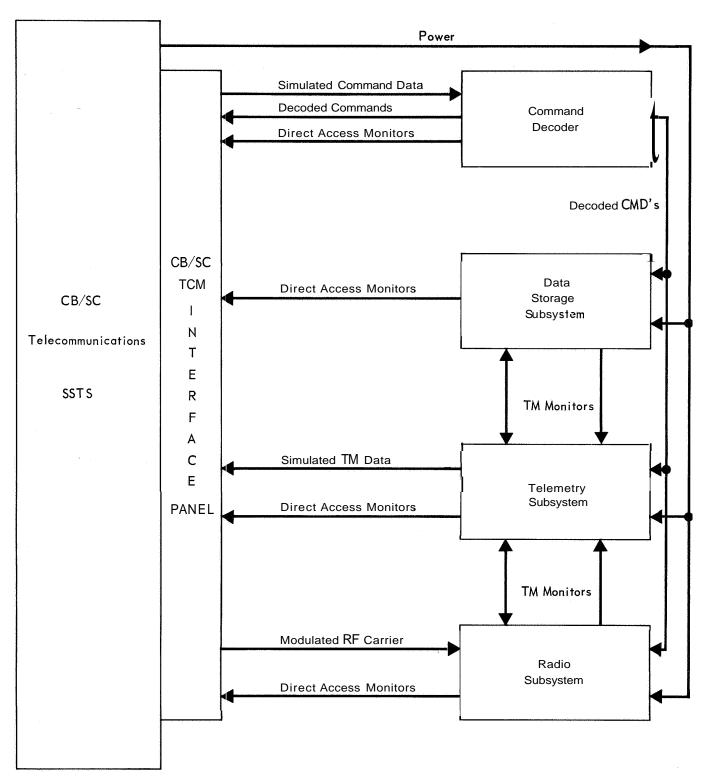


Figure **7.5–2**

SECTION 8

SOFTWARE

Software is the vital link between the operator, the test program, and the test equipment. It provides a means to translate commands, interconnect equipment, and gather and format the response data. Accurate and timely compilation of the data from the initial test to launch, and use of that data for analyses and decision making are significant requirements to ensure the success of the VOYAGER Program.

This section describes the total software package development and management for the Capsule Bus through checkout and launch. Where separable, program packages are identified and described for each checkout phase. The total OSE program is designed as an integrated hardware/software marriage, utilizing economic and reliability merits of each in reaching decisions for tradeoffs.

- 8.1 SOFTWARE MANAGEMENT Disciplined management of software packages ensures safe, reliable, and repeatable test sequencing and data processing, and provides uniform software documentation and control within major contractor task areas. Software configuration used in any given checkout operation must be uniquely identifiable and internal processing routines, as well as major test programs, are included in configuration control.
- 8.1.1 <u>Philosophy</u> Efficient software management requires that the total software package under development be divided into small manageable areas. Our packaging concept uses the natural division of discipline between machine language programming (support software) and test language programming (operational software) to establish logically separate software packages. These basic packages are further categorized as follows:
 - o Support Software for Subsystem Test Sets (SSTS)
 - o Operational (Test) Software for Subsystem Test Sets (SSTS)
 - o Support Software for Systems Test Complex (STC)
 - o Operational Software for Systems Test Complex (STC)
 - o Common (SSTS/STC) Support Software
 - o Mission Dependent Equipment (MDE) Software
- 8.2 SOFTWARE PACKAGING The following paragraphs describe the concept and configuration for support and operational software packaging of both SSTS and STC.
- 8.2.1 <u>SSTS Support Software</u> This software provides the basic tools for machine language conversion, program compilation and preparation of higher level software. Routine utility software and computer diagnostic/self-test programs fall into this category. Support software includes those program packages that would normally

be run off-line prior to or after a period of checkout or as background work in a time-shared system.

- 8.2.1.1 <u>SSTS Peculiar</u> The SSTS peculiar support software includes:
 - o A utility package comprising such programs as Memory Dump, Paper Tape Copy, Dump and Compare, Character Conversion Routines and other basic programs usually required for computer operation. This software is generally available from the computer manufacturer in a checked out and usable form.
 - o An assembler for generating machine language programs and possibly a Fortran type compiler. These will also, be supplied by the SSTS computer manufacturer in a checked out and usable form.
 - Computer diagnostics for both maintenance and on-line verification of the computer. These diagnostics must verify the operational readiness of the computer logic, computer memory, and all peripheral equipment. They will be furnished by the computer manufacturer and will be expanded as necessary to accommodate operational developments. In addition to this, the Capsule Bus contractor will furnish a self check diagnostic and readiness test for the Capsule Bus SSTS.
 - ^o A quick-look test results processor. This processor will produce hard copy output from the paper tape generated on-line by the SSTS computer during subsystem tests. The tape contains a record of all commands given and measurements made, with time, and provides an on-the-spot means of post-test trouble shooting, or near real time display of selected data.
- 8.2.2 <u>SSTS Operational Software</u> All SSTS test programs executed/interpreted in real-time constitute the SSTS operational software.

SSTS Peculiar

- o The basic SSTS peculiar operational program is the SSTS Executive. This program accepts mode control and direction from the control panel and provides positive indication of reception of direction. It also controls any displays in the SSTS and sequences all operations of the test equipment. The executive causes all command sequences, measurements, and time to be recorded on paper tape for post-test reports and trend analysis, and periodically self-checks the computer, without interruption of any test in progress. The program controls the remaining processors in the SSTS computer for all required testing. A typical executive flow is shown in Figure 8.2-1.
- The SSTS Input/Output Processor handles all input-output between its

TYPICAL REAL TIME CHECKOUT EXECUTIVE PROGRAM FLOW

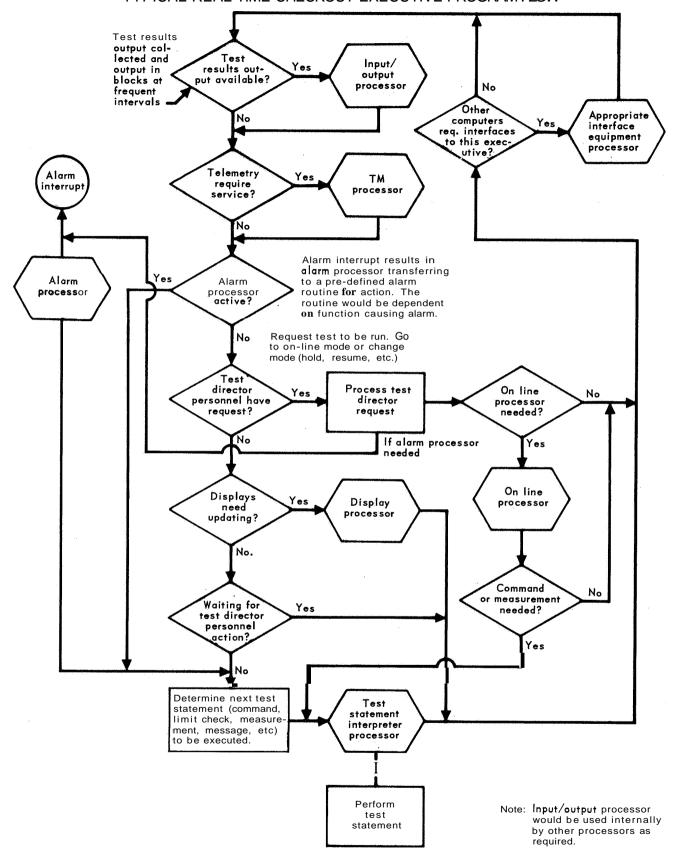


Figure 8.2-1

8-3

- computer and the remainder of the SSTS and between the computer and its peripheral equipment. All processors in the SSTS computer will use this processor for their Input/Output (I/O) to assure centralized control.
- O The Test Program Interpreter Processor functions under control of the Executive to keep track of test step numbers and to allow execution of each step of the test procedure. It accepts the output of the test procedures preprocessor and monitors execution of it. It also records and types test identification, date, time of day and serial number of equipment under test whenever it records a test sequence on paper tape.
- o The Alarm Processor executes shutdown routines if either the monitor/alarm interrupt occurs or if the test engineer requests it. These routines may be either permanently defined within the processor or defined by the test procedure in progress at the time of the alarm.
- o The On-Line Input Processor allows modification, during holds, of test limits or program logic and allows individual stimuli and measurement control from the typewriter. All actions in this mode are recorded as test results and will be included in any trend analysis or test results reduction.
- o The individual SSTS Test Procedures for each subsystem constitute the remaining operational SSTS software. Based on cost and schedule factors, these procedures will be written in the highest level language possible. The procedures will be executed under control of the Test Program Interpreter and will control application of stimuli, measure responses, compare measurements to limits in percent of full scale and output milestone or malfunction data on hardcopy, etc.
- 8.2.3 <u>STC Support Software</u> The STC support software is similar to the subsystem test set software and will be written in the System Test Complex (STC) computer machine/assembly language.
- 8.2.3.1 <u>STC Peculiar</u> The requirements for the STC peculiar support software are virtually identical to those specified for the SSTS in Section 8.2.1.1.
- 8.2.4 <u>STC Operational Software</u> All real-time STC test programs constitute the STC operational software.
- 8.2.4.1 STC Computer Peculiar
 - o The basic STC computer Peculiar Operational Software Program will be the STC computer Executive. This program will be the central controller in the STC computer, responsible for all sequencing of the various processors in the STC computer, for accepting mode control and direction from the test

director, and for keeping the test director aware of what is happening at all times. Data suppression will be accomplished when data varies by more than a specified amount on a line printer for any functions that the Test Director desires. The program will record command sequences, measurements, test site, range time, alarms, test procedure step numbers, etc. for post-test reports and trend analysis and will periodically cause the computer to cycle through self-test diagnostics.

- o The STC computer Input/Output Control Processor will handle data trans-mission between the computer and the test equipment, and between the computer and its peripheral equipment for the various processors and the STC computer Executive. All programs in the STC computer will use this processor to assure that all input/output is handled properly and to eliminate detailed 1/0 duplication.
- o The STC Test Program Interpreter will function under control of the Executive to keep track of test step numbers and to allow execution of each step of the test procedure. It will accept the output of the Test Procedure Preprocessor and monitor and control execution of the test program. It also will record and type out test identification, date, time of day, serial numbers of equipment under test, etc., whenever it executes a test or directs the SSTS to execute a test.
- o The STC Alarm Processor and On-Line Input Processor are similar to the SSTS processors described in paragraph 8.2.2.
- o The Display Processor will handle the updating of all CRT and related types of displays at fixed periods of time or at the option of the test director. The displays provide test data in engineering units. Out-of-tolerance values can be flagged as desired. The CRT-page type displays will show pre-planned measurement data. Fixed unassigned areas will be used for display of selected parameters at the test director's request, eliminating the need to change pages if a function needs monitoring but is not on the displayed page.
- o The SIC Launch Complex Equipment (LCE) and Deep Space Instrumentation Facility (DSIF) Interface Processors will allow communication with, or simulation of, the various other major support equipments. All interface programming dealing with these equipments will be included in these processors.
- o The individual test procedures for each subsystem or system will constitute

the remaining operational STC software.

- 8.2.5 <u>Common SSTS/STC Software</u> Depending upon the computer system(s) selected, the test language used, and physical proximity of the computers, common programs for SSTS and STC may be used. Examples described below are: the configuration data file maintenance processor, the test program preprocessor, and the test results processor. Common programs will be used to process or generate information relating to SLS, ESP and CB, as well as both the SSTS and STC computers.
 - O A configuration data file maintenance program will maintain a data base containing all the information that the automatic systems equipment documentation personnel and test operations personnel need for locating measurements or stimulus points.
 - o The test program preprocessor can be common for the SLS, ESP, and CB subsystems and systems test computers. This processor should accept test procedures in near-English and convert them to a format understood by the SSTS or STC Executives. The preprocessor will generate a listing of the test procedure along with step numbers, so that personnel can identify the exact point in the procedure if a hold is entered. The preprocessor will accept procedures for both the SSTS and STC. In this way, portions of a subsystem test, written for use at a vendor's facility, can be incorporated directly into a system test.

It is extremely important that no test sequence created by the computer software cause a situation to exist that is dangerous to either personnel or the equipment under test. To assure that such a sequence can not occur, the preprocessor automatically checks each procedure for improper sequences. This provides an additional safeguard over and above the safeguards and protective circuits in the system and subsystem test equipment. Use of the preprocessor has two other advantages: The subsystem or system engineer need not concern himself with the details of computer organization or a complicated programing language; procedures will be easier to understand and use; consequently the test operations personnel will require minimum training. A test results processor will be required which will accept either paper tape from the SSTS or magnetic tape from the STC. The program will be able to reduce entire tapes and analyze data or specific parameters between two given steps or times. The processor is a key element in the continuity and accessibility of the test history, and will perform trend

analysis and calculate elapsed running or cycle time of equipment under test.

- 8.2.6 <u>Mission Dependent Equipment (MDE)</u> The management, development, and documentation of MDE software for the Telemetry and Command Processor (TCP) computer are essentially the same as the approach described above for the STC computer. A similar packaging approach will be employed, except that the executive and processor programming requirements are significantly reduced. The major MDE software requirements are described in paragraph 4.5, Part D.
- 8.3 SOFTWARE DEVELOPMENT Because there are several manufacturers and vendors participating in the Capsule Bus program, it is imperative that software development be centrally controlled and coordinated. Language format, procedures and techniques will be developed by the Capsule Bus contractor and supplied to cognizant organizations. Test program software will be developed by the individual vendors involved in supplying the flight hardware and corresponding OSE, in conformance with these procedures. This centralized direction and control of software will be developed in concert with hardware design and test requirements integration, resulting in an effective and timely software and test program.
- 8.3.1 Philosophy McDonnell-Douglas experience in developing support/test software for the Saturn S-IVB Automatic Checkout System (ACS) has shown that strict central organization and control ensures the multitude of software interfaces will mate under all environments. Consistent, complete documentation, concurrent with program development, will minimize field support and maintenance staffing. Common software between test area and checkout systems will minimize software maintenance costs, maximize program reliability, and assure test sequence repeatability between areas. This is particularly true of the test language where the customer, vendor, and the Capsule Bus test engineers must think in common terms.
- 8.3.2 <u>Development Phases</u> In general, software development has four phases: definition, programming, debugging, and production. These will be described in detail below.
- 8.3.2.1 <u>Support Software Development</u> Figure 8.3-1 is typical of support software development. The total software package provides maximum reliability and flexibility to fully utilize available computing equipment. Consistent with the total software design concept, individual programs will be defined in detail in Software Request Documents (SRD). Once the SRD is approved, detailed subroutine specifications will be prepared followed by analysis, flow charting, and coding. The individual routines and checkout drivers will be assembled/compiled, desk checked, and debugged. Then the entire program will be debugged as an entity prior to documentation and

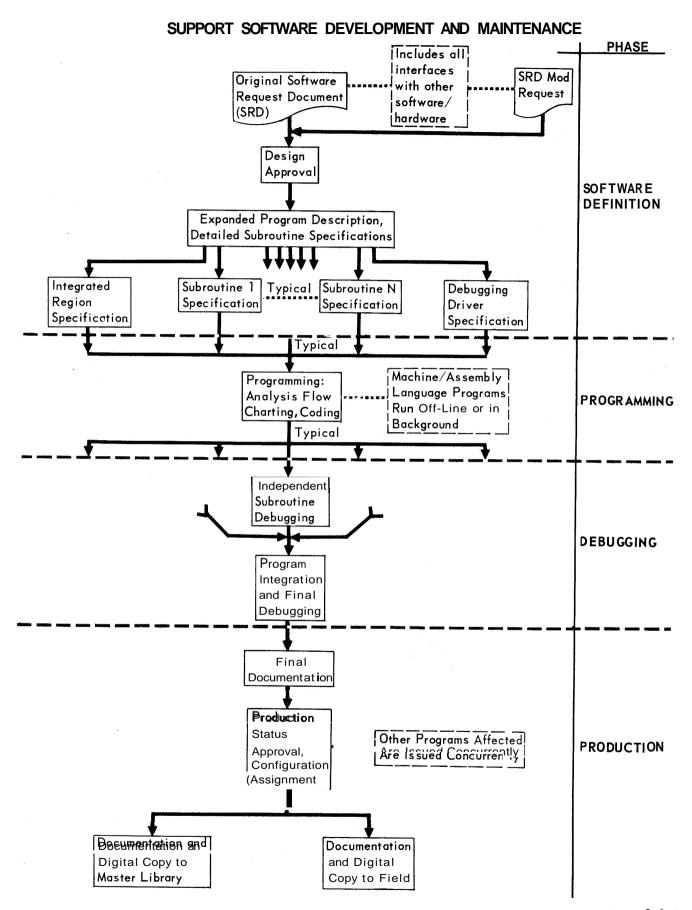


Figure 8.3-1

approval for production status. A central library of test programs (digital and hard copy) will be maintained at the Capsule Bus contractor's factory, with a satellite library at KSC and appropriate vendors.

- 8.3.2.2 Operational Software Development The procedures shown in Figure 8.3-2 are typical of test program development. A minimum number of test programs will be developed to fully checkout the Flight Capsule and its subsystems in all of its operating modes. A Test Requirement Document (TRD) will be prepared to completely define the purpose of the test, the equipment to be tested, and the test sequencing, constrained by the operating concepts. The test programs will be prepared from approved TRD's in the VOYAGER test language. The preprocessor will process the source test program and produce a test sequence listing and an object program for operation under control of the Executive. It also will produce error notes for use in correcting the programs. Once the program listing is free of error notes, the program will be run against the Integrated Subsystem Bench Test Unit (ISBTU) which will serve two purposes: test operations personnel will become familiar with the test procedure and OSE equipment operating concepts; and further debugging of test procedures and test equipment will be accomplished. The checked-out test program will then be copied; one copy will be distributed to each using area, with the master retained at the tape library. Prior to mating with equipment to be tested, OSE TRD's will be written for self-test of the OSE. A typical test phasing plan for a checkout area is depicted below:
 - o OSE manual setup/calibration procedures.
 - o Automatic OSE end-item setup/self-test procedures.
 - o Automatic OSE self-test (with special patching/routing command signals to measurement channels).
 - o Automatic OSE configuration self-test (patching configured to match the system under test).
 - o Mate to Subsystem Bench Test Unit or Proof Test Model for test development which will be phased to minimize the possibility of endangering equipment due to improper manufacture or test sequencing.
 - o Mate to capsule/subsystem and perform automatic checkout with checked out test programs.

Test results processing will be performed to augment on-line test milestone and malfunction data for post-test troubleshooting and selloff. Test results processing will be used extensively during the initial test development and test director training phases.

TEST PROGRAM DEVELOPMENT AND MAINTENANCE

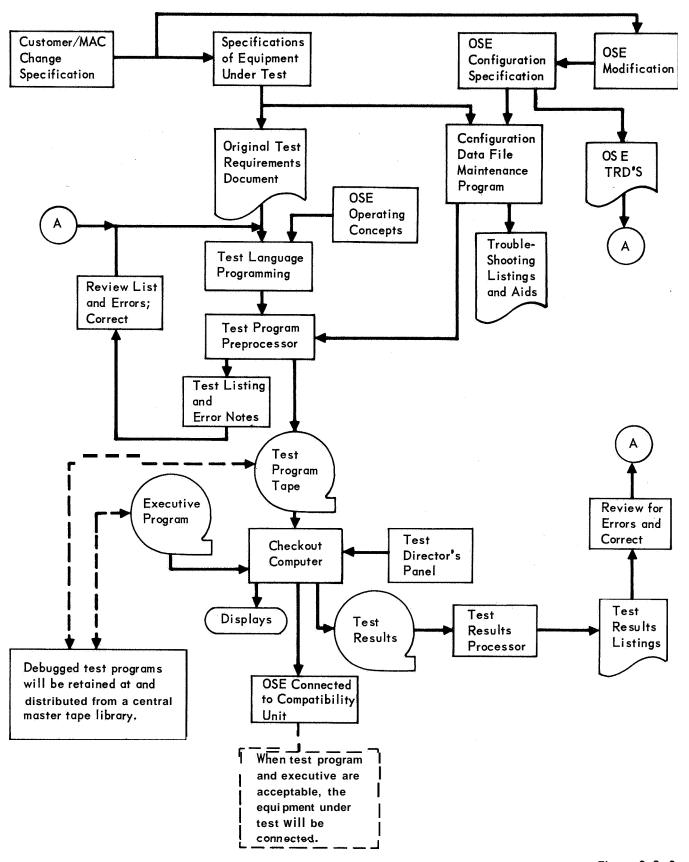


Figure 8, 3-2

8.4 SOFTWARE CONTROL/DOCUMENTATION — A Software Request Document (SRD) will be required to define pertinent specifications for the support program. The actual programming will begin only after the specifications, including hardware and software interfaces, are reviewed and approved. A Test Requirement Document (TRD) also will be required for the test procedures including all sequences necessary for any potential hardware/test director actions, prior to compiling a test program. Detailed, standard format documentation must be provided. Support program/routine descriptions will include input/output specifications, interface formats, flow charts at the detailed subroutine level, and assembler/compiler listings annotated with functional explanations. Test program documentation also will include a description of the equipment under test, a functional schematic/block diagram, a brief description of the purpose of the test, and the test language processor listing, which will contain remarks describing major blocks of test.

All support and operational software are circumscribed by the following software standards:

- a. Modular programming, applying subroutine techniques, will be used. Standard format conversion routines, table lookups, etc. for use by all programs will minimize programming development time.
- b. For built-in error checking and diagnostics, the Executive-Supervisor will contain a computer diagnostic routine that will be performed periodically, possibly between test statement execution. A built-in software sensing feature will verify that all executive program tasks are being performed.
- c. Independent routines will be checked out separately, using a building block approach, then integrated and debugged. The test cases and simulated software interfaces used for debugging will become a part of the routine/program documentation for later use.
- d. Uniform man-machine communication formats will be used to eliminate incorrect message interpretations and enable positive command/control and test intervention as required.
- 8.4.1 <u>Test Procedure Language</u> Following are brief descriptions of the advantages and disadvantages of the four principal programming techniques:
 - a. Machine Language
 - b. Fortran, etc.
 - c. A Fixed-Format Test Language
 - d. A Free-Format Test Language

<u>Machine Language</u> requires a programming specialist to program the computer at a low level of machine instruction. Many programming steps are required for even a simple operation. Machine language is detailed and extremely complicated, and requires trained programmers to produce efficient and useful programs. Programmers would be required at each test area to prepare and maintain test programs.

Fortran is an algebraic, higher level, scientific language. It can be used to write programs in a simpler form than machine language, but they would bear no resemblance to manual procedures and a great deal of additional training would be required before operations—type personnel could understand them. Also, large Fortrantype programs required on Voyager rapidly become as complicated and difficult to understand as machine language programs. It is probable that frequent excursions into machine language would be required, and obscure capabilities of the language would have to be used to achieve the capabilities needed for checkout.

<u>Test Languages</u>, both Fixed and Free Format, have been used in automatic checkout by several contractors in the past, including McDonnell-Douglas. These languages, e.g. Saturn Test-Oriented Language (STOL), are usually oriented to general checkout, with some features unique to the parricular system due to peculiarities in designs.

In a Fixed Format Language, fixed columns on an IBM card are reserved for the operator, the operand, etc. The cards must be filled exactly or the test language preprocessor program will consider it an error, thus necessitating a rerun because no object code would be generated.

In most <u>Fixed Format Languages</u> the operand field is not large enough for a standard component title or even a recognizable abbreviation. Thus, the test programmer must know the system and OSE configurations well in advance of testing, unless dummy symbols are assigned to known commands and measurements and later defined to the preprocessor or Executive by a cross-reference index. It is also awkward to provide for retention of several measurements so that arithmetic operations may be performed with a fixed field language.

In a <u>Free Format Test Language</u> such restrictions are minimized or do not exist at all, as demonstrated in one checkout language used currently on the Saturn Program (STOL).

Summary

Both the Fixed and Free Format Test Languages especially the latter, are far easier to understand and use than either Fortran or Machine Language. They do require a special preprocessor to be written which will convert from the test language (English) form to a language the computer understands. The free format preprocessor

is more difficult to write than the fixed format preprocessor. However, it is believed that amortizing the free format test language preprocessor costs over the length of the VOYAGER program will cost less than the use of machine or Fortran languages when we consider the personnel training costs required for fixed format language implementation. On this basis, a Free Format Test Language is recommended for Capsule Bus software.

8.5 SUPPORT FACILITIES NEEDED - The SSTS peripheral equipment and memory are necessarily limited by cost considerations. Therefore, test tapes will be generated on another computer. Depending on frequency of changes for the SSTS programs and availability of the STC computer(s), an interesting approach to this requirement is the use of the STC computer as a support computer for SSTS's as well as for the STC itself. A detailed trade study of computer loads and availability will be conducted to establish the usability of this approach.

SECTION 9

OSE EQUIPMENT SUMMARY

The Capsule Bus Operational Support Equipment requirements identified during Phase "B" are tabulated in Figure 9-1. Included in this summary are simulators, handling equipment, and Mission Independent Equipment, which are considered GFE and are to be supplied by NASA or other system contractors.

Figure 9-1 illustrates equipment required at the primary using areas, but does not indicate the quantity required. Prior to Phase C, a schedule and quantity analysis will be conducted to provide a more detailed site utilization and the exact quantity of OSE required at each site. Additional study will be conducted to determine the OSE requirements for support of development and qualification testing of the terminal guidance subsystem at Langley and the aero decelerator and reaction control subsystems at White Sands.

OSE EQUIPMENT SUMMARY

CAPSULE BUS SYSTEM

	AREA I	JTILIZATIO	<u>N</u>
OSE	FACTORY	KSC	DSN
SYSTEM TEST COMPLEX (SIC)			
Test Directors Console	X	X	
TCM Instrumentation Console	X	X	
Power & Distribution Console	X	X	
Sequencer & Pyrotechnics Console	X	X	
Radar Console	X	X	
Guidance & Control Console	X	X	
Propulsion & Thermal Console	X	X	
Timing Distribution System	X	X	
Data Conversion Unit	X	X	
Magnetic Tape Recording System	X	X	
Strip Chart Recorder Group	X	X	
Voice Communication System	X	X	
(Ref. MDE List)	X	X	
ZMTM & Command Processor (TCP) Computer	X	X	
23 TCP Peripheral Equipment	X	X	
Computer Data System (CDS)	X	X	
CDS Peripheral and Interface Equipment	X	X	
Junction Box	X	X	
·Mobile Maintenance Cart	X	X	
Complex Cabling	X	X	
Ground Data Transmission System (GDTS)	X	X	
Pyrotechnic Test Kit		X	
TV Monitor		X	
2 Countdown Timing and Display		X	
Canister and Adapter Simulator	X		
Capsule Lander Simulator	X		
SLS Simulator	X		
ESP Simulator	X		

Figure 9–1

	AREA UI	TILIZATION	
OSE	FACTORY	KSC	DSN
Spacecraft Simulator	X		
Capsule Bus to SC Simulator	Used at SC (Contractor'	s plant
Capsule Bus to SLS Simulator	Used at SLS	Contractor	r's plant
Capsule Bus to ESP Simulator	Used at ESP	Contractor	r's plant
SC Mounted CB Support Equipment Simulator	Used at SC C	Contractor'	s plant
LAUNCH COMPLEX EQUIPMENT (LCE)			
Launch Monitor Console		X	
Hazard Alarm & Monitor System		X	
Ground Power & Distribution Equipment	X	X	
Remote Stimulation Equipment	X	X	
UHF Receiving System	X	X	
MISSION DEPENDENT EQUIPMENT (MDE)			
DSIF Data Demultiplexing Equipment	x <u>1</u>	x <u>1</u>	X
1 DSIF Command Interface Equipment	x <u>1</u>	x 🚹	X
Capsule Bus Simulator			X
SFOF Engineering Display Equipment			X
SFOF Display Interface Equipment			X
SFOF Capsule Bus Control Console			X
SFOF Quick Look Displays			X
SUBSYSTEM TEST EQUIPMENT (SSIE)			
Electrical Power Subsystem Test Set (SSTS)	X	X	
Pyrotechnic SSTS	X	\mathbf{X}	
Sequencer SSTS	X	X	
Thermal Control SSTS	X	X	
Telecommunications SSTS	X	X	
Guidance & Control SSTS	X	X	
Radar SSTS	X	X	
Propulsion SSTS	X	X	
ASSEMBLY, HANDLING & SHIPPING EQUIPMENT (AHS	<u> </u>		
CB Handling Fixture	X	X	
CB Work Stand	X	X	
CB Handling Dolly	X	X	

Figure 9–1 (Continued)

		AREA U	TILIZATION	
	OSE	FACTORY	KSC	DSN
	CB Handling Sling	X	X	
	CB Weight & Balance Adapter	X		
	Flight Capsule Transporter	Move to	KSC with CB	
	Air Transportation Adapter	Move to	KSC with CB	
	Capsule/Canister Assembly & Checkout Stand	X	X	
	Aft Canister Work Stand	X	X	
	Forward Section Canister Dolly	X	X	
	Forward Section Canister Sling	X	X	
	Canister Handling Sling	X	X	
	CB Adapter Fixture	X	X	
	Lander Handling Fixture	X	X	
	Lander Installation Fixture	X	X	
_	CB Alignment Kit	X	X	
<u> </u>	SLS Handling Fixture	X	X	
<u> </u>	SLS Hoisting Sling	X	X	
<u> </u>	SLS Shipping Container	X	X	
	Auxiliary Hoist Control	X	X	
	CB Mechanical Simulator	X		
	Deorbit Motor Handling Fixture		X	
	Deorbit Motor Installation Fixture		X	
	GHe/GN ₂ Servicing Unit	X	X	
	${ m N_2O_4}$ Servicing Unit		X	
	N ₂ O ₄ Flush & Purge Unit		X	
	Launch Pad Propellant Disposal System		X	
	Canister Pressurization Unit	X	X	
	ESF Propellant Disposal System		X	
	^N 2 ^H 4 Service Unit		X	
	N ₂ H ₄ Flush & Purge Unit		X	
	MMH Service Unit		X	
	MMH Flush & Purge Unit		X	
	Propulsion Subsystem Tool Set	X	X	

Figure 9–1 (Continued)

AREA UTILIZATION

OSE	FACTORY	KSC	DSN
SPACECRAFT MOUNTED CB SUPPORT EQUIPMENT OSE			
CB/SC Mounted TCM Subsystem Test Set	x	Х	



MDE/Duplicate used at STC

GFE Supplied by NASA or Voyager System Contractor

Mission Independent Equipment (MIE) used in STC

SECTION 10

SUPPORTING ANALYSIS AND TRADE STUDIES

This section contains a discussion of the approach to OSE concept selection, a list of selected concepts and alternatives, and the trade studies and analyses to support the major concepts. A summary of the major OSE concept alternatives evaluated during Phase B, and the selected approach are illustrated in Figure 10-1. Significant concepts documented by trade studies are sumarized in Figure 10-2. 10.1 CONCEPT SELECTION APPROACH - The selection of OSE concepts follows a system engineering logic pattern similar to that used for flight subsystem selection. The process relies heavily upon engineering judgement and experience coupled with a knowledge of the VOYAGER objectives and Capsule Bus design and test requirements.

Ground Operations and Test Plan - The Integrated Test Plan (Vol. VI, Part B) describes the test and operations performed on the Flight Capsule from equipment installation to launch. Functional analysis of this plan establishes the test and operations requirements and forms the basis for OSE concepts. Feedback and iteration of OSE and test concepts are maintained throughout the concept selection process.

Capsule Bus Flight System Design - The initial design of the Capsule Bus System is analyzed to establish preliminary functional and test requirements. The irteraction of OSE and flight systems engineering is emphasized in areas such as test point availability and accessibility, test stimuli and monitoring, use of inflight checkout and built-in-test, depth of fault isolation, handling, and transportation. The preliminary OSE concepts are fed back through flight systems engineering for evaluation, and the flight system to OSE interfaces are integrated as a balanced system.

<u>Project Level Selection Criteria</u> - The OSE concept selection is based on VOYAGER project level selection criteria values developed by Flight Capsule systems integration engineering, as follows:

Probability of Mission Success	.35	Flexibility	.15
System Performance	.20	cost	.10
Development Risk	.20		

The program selection criteria is translated into unique OSE selection factors that are meaningful to the evaluation of a particular type or configuration of OSE. A list of typical OSE selection factors is shown in Figure 10.1-1. A standardized

BASELINE CONCEPT SUMMARY

OSE CATEGORY	OPERATION	ALTERNATIVES AND SELECTED BASELINE	REMARKS
Subsystem Test Sets	Degree of SSTS Test Automation	Selected Automatic with Manual Backup	Minimizes total test time. Reduces operator-induced malfunctions Quick reaction to critical conditions. Rapid malfunction verification Facilitates test repeatability. Flexible for equipment growth thru total program life.
	Central or Local Automatic Control	- Lecal	 Independent of central control – maxin um test flexibility. allows simultaneous subsystems testing. operation not affected by central corttrol down time permits possible usage of SSTE at vændor's facilities or remote test sites. permits independent OSE self-tests. Complex programming and computer interface
	Test Sequence Control and Comparison	(Small, digital, general purpose) Purpose) Punched tape	High reliability. Possible reduction in central computer memory requirements. Self-test easily implemented. Quick reaction. Random access permits test flexibility. Minimizes central computer interface. Moderate cost Possibly lowest in cost. Relatively high cost. Inflexible — not easily modified.
	Test Parameter Monitoring	Digital Readout (Analog readout as required) Analog Meters	• Increases test repeatability – reduces interpretation error. • A/D conversion facilitates:
	Test Data	Hard-Copy Printer	-5

Figure 10-1

10-2-1

Q ST

 a Reduces visual display requirements bermits time-sharing of display, plus callup capab li #y Provides printout of telemetry data to SS engineer. € Each subsystem test data compiled separately. Minimum cost 	 Oscillograph, X-Y plotters as required by each SSTE. Data directly available to subsystem engineer. Data inaccessible to subsystem engineer during test. 	 Makes all SSTE data time coherent. Requires synching for systems testing Recorded data loses significance. 	 Expedites OSE maintenance. Limited due to use of off-shelf support equipment. Provides OSE operational status. Requires support equipment for OSE. Time-consuming. 	 a Provides alarm raniforing of bo ↑↑ ↑ M and direc* subsystem data. Incomplete monitor capabilities Restricts independent SSTS operation. 	a Maxiaum cab'ing disassemblx and hookup time a Maxiaum con∕idence io STC verification	a May not be compatible with STC facilities and associated contractors implementation.	 Does not provide for automatic est sequence operation High repeatability Reduced test time Imposes operational complexities on operating personnel. No real savings in test and display functions. Creates more complex equipment High repeatability Reduced test time Not computer dependent for critical displays and commands. Not software dependent for test sequencing. Maximum expandibility and flexibility for future requirements. May interfere with Apollo operations. Further study intended.
a Ce. fral printer	Local Recorder (each SSTE) Central recorder	Central Clock for all SSTE. Individual clock	Fault Isolation to Depth Possible) Malfunction verification only.	Local (SSTE) and Central Alarm Capability Local alarm only	 Entire STC (Equipment, Data Links, and cabling) moveable Equipment and interconnecting cabling moveable data links fixed. 	• Van mounted STC	Mariner C approach (Analog displays and computer controlled data evaluation) Mariner C approach and semirautomatic test sequencing and manual backup New System, fully automatic — closed loop with matic — closed loop with manual backup Use existing Apollo ACE
	Analog/Bi-Level Recording	Data Time Tagging	OSE Self-Test (Malfunction verifi- cation to OSE or flight subsystem a constraint - 5.2.1.h)	Alarm Monitoring	System Test STC Mobility		Degree of Test Automation
					System Test Complex (STC)		

BASELINE CONCEPT SUMMARY (Continued)

REMARKS	High flexibility Accurate Capable of symbolic display Requires more panel space. Requires D/A conversion Limited accuracy	 May not comply with constraint document Maximum DSN compatibility: TCP and software in STC is identical to TCP and software in DSIF. 	▲ Customer to onfirm Çandidate log tin pre ently wsed by Mariner)	 Slow reaction time during emergency. Power supplies are located at remote sites. Centralized control and monitor from STC provides maximum coordination with other systems. 	 Facility emergency diesel generator may not meet the launch probability requirements. Emergency batteries provide power to monitor critical parameters and sequence capsule to a safe condition in the event of a total facility power failure. 	 Compatible with TCM command subsystem More suitable for transmission of commands over STC to launch pad distances Difficult to transmit over long distance. 	Readily accessible, no flight weight. High weight penalty Complates fl⊋ht HCM des:gn
ALTERNATIVES AND SELECTED BASELINE	Digital Alpha-Numeric CRT Digital readouts (NIXIE, projection, etc.) Analog meters	Use dual program capability of TCP computer for both MDE operations and ground test operations. Use TCP computer for MDE operations only and provide separate computer (CDS) for ground test operations	Hangar AO Alternate existing location (MSO) New location	 Local control and monitor Remote control and monitor 	FacilitiesHazard Alarm Batteries	Digital Test Commands Analog Test Commands	External MPX Add test MPX to flight System Expanded flight TCM
OPERATION	System Test Data Display Method	STC – Computer Usage	STC Location at KSC	Ground Power Control	Emergency Backup Power Source	Ground Data Transmission	Test Data Multiplexer
OSE CATEGORY	System Test Complex (STC)			Launch Complex Equipment (LCE)			

Figure 10-1 (Continued)

smission of data over long .D. / for communication of .l to LCC.	on of radio portions of TCM during system and pre-	utions of the stander of malfunctions ent.	system status for evaluation/ equate visibility or control	flue at owance — se o da y lazardous. er Guppy**) capable. y when available. spension — limited flying	ntegral capsule rotation and positioning — maintaining cleanliness a potential problem. or op rati nal fle A lity — Has'er to clean		- no correction factors required. npensation o ESF with propellant leak I vapor detection equipment at
 Wideband A2A telephone pairs available (digital link) Digital method preferred for transmission of data over long lengths involved from STC to PAD. Selected hardlines used primarily for communication of critical signals and power control to LCC. 	 Conflicts with RF range utilization Will not provide end to end test Radio link for DSIF verifications of radio portions of TCM subsystems Primary reliance on hardline link during system and prelaunch testing. 	 Interference with prelaunch operations Centralized fault isolation in control room plus direct test point access (OSE connector) for verification of malfunctions which indicate capsule replacement. 	 Maximum display per unit of panel space. Test conductor can view any subsystem status for evaluation/decision. Test conductor does not have adequate visibility or control 	 a Long sH'pping time mqu'res scHeWwle allowance — se o demode a Acceptable route questionable. Hazardous. Only one existing airplane ("Super Guppy") capable. Utilization of C—5A a possibility when available. Capsule carried externally by suspension — limited flying range. 	r with ir ility. complex	JPL guidelineReduced capsule weight.Better quality propellant.	 Direct approach – most accurate – no correction factors required. Requires temperature/density compensation Hazardous moving vehicle back to ESF with propellant leak Requires propellant handling and vapor detection equipment at pad.
only Digital Downlink Test Data Plus Selected Hardlines	Radio data link only Ardline data link only Both hardline and radio links	Local (Pad) fault isolation and malfunction verification Remote (control room) fault isolation and malfunction verification Remote fault isolation plus local malfunction verification	Centralized alpha-numeric CRT display Intercom + Go/No Go status displays, controlled by subsystem test engineers	a Barge – River/Ocean Rowte. a Highway	 Capsule transport and handling trailer Capsule dolly plus separate capsule erecting fixture 	Sterilization Sterilization Sterilization sterilization chamber	Weight Volume None Provide capability to unload propellants at pad
Irdnsmission	SLS Ground Data Transmission (Radio vs Hardline)	Fault \$ olation Concert B	Test Conductor Console Display	C psulo Transport	Capsule Handling (intra-facility mobility and positioning)	Propellant servicing	Propellant Quantity Measurement Propellant Disposal at Launch Pad
				Assembly, Handling and Support Equipment (AHSE)		AHSE (Servicing)	

SUMMARY OF MAJOR OSE TRADE STUDIES

TRADE STUDY	REMARKS
SSTS Automation Selective Automatic vs Manual Mode	Minimum Test Time Hi Speed Self Check and Alarm Monitor Maximum Repeatability and Accuracy Cost Effective for Selected Subsystems
STC Displays Digital Displays vs. Analog Meters vs. [C RT Displays]	 Minimum Operator Error Hi Density Display Saves Space Max Flexibility and Growth Potential
CB_ <u>Transportation Mode</u> Barge vs. Highway vs. Helicopter vs. Aircraft	Least Schedule Impact Barge is Backup Mode
CDS Computer Selection SDS 920 vs. 3rd Generation	 Maximum Flexibility & Growth Minimum Test Time Potential for Contractor time sharing
<u>SSTS</u> Automation Method Hard Wire Logic vs. Tape Reader vs. <u>Desk</u> Top Computer]	 Cost Effective for Highly Repetitive Sequential Operations Max Flexibility and Growth Provides Independent Subsystem Test

OSE SELECTION CRITERIA AND FACTORS

PROGRAM CRITERIA	TYPICAL OSE SELECTION FACTORS
Probability of Mission Success	OSE reliability Affect on flight subsystems OSE redundancy and backup
OSE and Flight System Performance	Test quality Test time (operator, OSE, flight system) Test confidence Degree of self test Degree of fault isolation
Development and Schedule Risk	OSE operational availability (MTBF) Relative "state-of-art" OSE initial availability
Versatility (Flexibility)	Growth potential Choice of operating modes Potential common usage Adaptability to future missions
Cost	Test cost (operators time) OSE hardware cost OSE maintenance cost OSE development cost Software cost

numerical scale from .2 to 1.0 is used to rate the selection factors for each alternative in terms of its contribution to the VOYAGER project level selection criteria, as represented by the weighted totals shown in the detailed trade studies.

Cost factors are weighed carefully in the evaluation of alternative OSE approaches. The ratio of test effectiveness to total test cost is equated to determine cost-effectiveness. A major factor in Capsule Bus OSE effectiveness is its contribution to the probability of launch-on-time.

- 10.2 TRADE **STUDIES.** The major trade studies conducted during Phase B are as follows:
- 10.2.1. Trade Study-Subsystem Test Sets Automation Concept
- 10.2.1.1 <u>Purpose and Scope</u> The objective of this trade study is to determine the optimum approach to controlling and monitoring support equipment for flight subsystems testing. Three alternatives were analyzed for compliance with the constraints and test plan: (1) manual control and monitor capability only; and (2) selected subsystem test sets with automatic control and monitor and a manual backup mode, and (3) total automatic with manual backup.
- 10.2.1.2 <u>Summary</u> Results of the study indicate that selected subsystem test sets should be automated if the types and number of tests, mechanization complexity, test time, and other related factors warrant or offset the costs. Manual (non-computer dependent) backup should be provided for the automated test sets.
- 10.2.1.3 <u>Functional and Technical Requirements</u> Design of the subsystems test sets are constrained by several factors:

The SSTS must be capable of:

- o Manually controlling its subsystem to any operating mode and in any sequence, provided for by the normal subsystem test circuitry.
- o Performing all required test routines expeditiously, correctly and repeatably \blacksquare
- o Providing self-test capability without test interruption for isolation of problems to OSE or related Capsule subsystem.
- o Interfacing with a general purpose computer for test sequence control or direction and data acquisition and display.
- 10.2.1.4 <u>Approaches and Significant Selection Factors</u> Three basic approaches were considered initially: (1) manual only, (2) total automatic with manual backup, and (3) the automation of selected Subsystem Test Sets with a total manual capability. The second approach (total automatic with manual backup) was eliminated from further consideration since testing of some subsystems is best accomplished

manually. The two remaining alternatives are presented with the significant factors affecting the baseline choice.

Selected SSTS Automated:

- o Maximum probability of mission success
- o Reduces total test time
- o Reduces possibility of operator-induced malfunctions
- o Reduces interpretation errors
- o Reduces operator fatigue due to automatic cycling of repetitive tests
- o Provides rapid malfunction verification
- o Facilitates test repeatability
- o Makes use of the constraint-required general purpose computer interface while in the autonomous subsystems test mode.
- o Maximum flexibility and growth potential for follow on missions.

Manual Mode Only:

- o Lowest in costs.
- o Retains the operator in the decision-making loop.
- o Higher OSE equipment reliability.
- 10.2.1.5 <u>Recommended Approach</u> The results of the numerical evaluation (Figure
- 10.2-1) indicate that the optimum approach to SSTS control and monitor is to selectively automate the support equipment to the extent practical.
- 10.2.2 Trade Study System Test Complex Display Techniques
- 10.2.2.1 <u>Purpose and Scope</u> This trade study was conducted to determine the optimum data display method to be used for display of test parameters at the System Test Complex (STC).
- 10.2.2.2 <u>Summary</u> The alpha numeric Cathode Ray Tube (AN/CRT) display is the optimum display method. The major factors contributing to its selection are high probability of mission success, flexibility and growth potential for follow on missions, and low development risk.
- 10.2.2.3 <u>Functional & Technical Requirements</u> The display should readily convey the correct value of the measured parameter to the operator. Desirable features are ease of parameter identification, minimum read time, and ease of operator interpretation. For this study, the incoming data is assumed to be in digital form with parameter identification. Each measurement will be scaled to facilitate display in engineering units.
- 10.2.2.4 <u>Design Approaches and Significant Characteristics</u> Five methods were studied:

Alpha Numeric Cathode Ray Tube (AN/CRT) - Displays (in english language and engineering units) the parameter identification, range, value, and limits for a virtually unlimited quantity of measurements. Also capable of displaying a wide range and format of statements and graphical data. This method requires considerable logic for character generation and formatting.

<u>Decimal digits with the scaling performed by the computer</u> - Displays the parameter in digits with the engineering units mechanically attached to the front panel adjacent to the display. The only logic is that required to store the scaled value between computer updates.

<u>Decimal digits with local scaling</u> - Uses the same display as the previous one but receives unscaled data. A digital multiplication scheme is required for each group of displays, but the incoming data can originate from any digitized source.

Analog Meters with computer performed digital to analog conversion (DAC) - Performs scaling mechanically by selecting a meter'scale which is graduated in appropriate engineering units.

Analog Meters with DAC's located in the display panel - Accepts digital data from any source and performs digital to analog conversion locally. The scaling is performed as in the previous method.

10.2.2.5 <u>Evaluation</u> - The trade study results are summarized in Figure 10.2-2. The selection factors used were chosen to emphasize the approach differences, i.e., factors which are equally favorable or unfavorable to all concepts are not mentioned. Pertinent factors affecting the baseline choice are shown below.

AN/CRT

- o High reliability and readability
- o Flexibility and growth potential to support follow on missions.
- o Low development risk (units are developed and off-the shelf)

Decima1

- o Average flexibility for expansion
- o Will not accommodate special formats
- o High hardware costs

Meters

- o Low readability
- o Low accuracy
- o Average flexibility for expansion
- o Will not accommodate special formats

- 10.2.2.6 <u>Recommended Design Approach</u> The AN/CRT is the best display technique. The computer scaled decimal display is second. The flexibility of the AN/CRT to support expanded or changing display requirements is the major factor contributing to its selection.
- 10.2.3 Trade Study-Voyager Flight Capsule Transportation Mode
- 10.2.3.1 <u>Purpose and Scope</u> Investigation of alternate shipping methods to determine the optimum mode for transporting the Flight Capsule from the contractor's facility to KSC.
- 10.2.3.2 <u>Summary</u> The four transportation methods examined are: (1) Airplane, (2) Helicopter, (3) Barge and (4) Highway.
- 10.2.3.3 <u>Functional and Technical Requirements</u> A major constraint to transporting and providing mechanical and environmental protection to the flight equipment while in transit is the size of the Flight Vehicle (Approximately 13 ft high x 20 ft dia.).
- 10.2.3.4 <u>Design Approaches and Significant Characteristics</u> Four methods were studied:

<u>Airplane</u> - B-377SG (Super Guppy) is the only aircraft with a large enough cargo area to hold the Flight Capsule with its transporter.

<u>Helicopter</u> - A number of different helicopters have the capability of lifting and moving the Flight Capsule by exterior cable suspension.

<u>Barge</u> - Numerous barge models possess the capability of transporting the Flight Capsule. Mississippi and/or Missouri River-Ocean route would be utilized. Local movement: from contractor's facility to barge loading site would be by Helicopter.

<u>Highway</u> - Design of a suitable Flight Capsule transport with the over-the-road capability is possible utilizing standard tractor (truck).

10.2.3.5 <u>Evaluation</u> Figure 10.2-3 summarizes the study results. The major evaluation factors are as follows:

<u>Airplane</u> - B-377SG an airplane (with loader) is capable of Flight Capsule transport. Shipping time is the least of all methods, however, only one B-377SG aircraft exists. Protection against atmospheric pressure changes required.

Helicopter - External suspension and limited flying range (requiring multiple setdowns) present significant hazards.

<u>Barge</u> - Shipping time (10 days to two weeks) is the longest of any method. Environmental protection is required.

<u>Highway</u> - Because of traffic loads, road width and overhead clearance constraints, no feasible route was discovered.

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Figure 10.2-1

COST FLEXIBILITY (FACTOR = .15) DEVELOPMENT RISK (FACTOR = .20) SYSTEM PERFORMANCE (FACTOR = .20) (FACTOR = .35)PROBABILITY SUCCESS (Ps) **OF MISSION** PROGRAM LEVEL CRITERIA AND VALUE

Figures 10.2

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CAPSULE TRANSPORTATION MODE

Figure 10.2-2

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10.2-2, 10.2-3

10-10-2

- 10.2.3.6 <u>Recommended Approach</u> Because of its capability of safely accomplishing the task in the least possible time, the aircraft mode was selected as the most feasible transportation method with barge transportation as a backup mode.
- 10.2.4 Trade Study-Computer Data System (CDS) Computer Selection
- 10.2.4.1 <u>Purpose and Scope</u> This trade study was conducted to determine a functional group of candidate computers from which a final selection can be made (during Phase C) for the Computer Data System (CDS) computer in the System Test Complex (STC).
- 10.2.4.2 <u>Summary</u> The study results clearly show that the final selection of the CDS, including its configuration, (i.e., core memory size, input/output controllers required, special purpose peripherals, etc.) should be made from those computers in the "third generation" category as defined herein.
- 10.2.4.3 <u>Functional and Technical Requirements</u> The candidate computers must, as a minimum, meet the following functional, and technical requirements:
 - o All requirements and constraints of Part D, Section 4.3.9.2 of this volume (Computer Data System).
 - o Possess the expansion capabilities necessary to meet follow on VOYAGER missions with a minimum of hardware and software changes.
 - o Provide flexibility in design and configuration to meet changes in interface and commonality requirements.
 - o Provide maximum compatibility with anticipated updating of the DSIF and SFOF computer systems planned for VOYAGER missions.
- 10.2.4.4 <u>Design Approaches and Significant Characteristics</u> For the purpose of this study, computers are classified in functional groups rather than hardware groups. Three significant organizational and functional groups of computers are defined.

<u>First Generation Computers</u> - Those which use electro-mechanical relays, vacuum tubes, and limited discrete solid state components. All are synchronous in operation and have a characteristic design that is processor oriented. The software mode of operation uses sequential programming and its design is characteristically centered about a single system operating in a single mode.

<u>Second Generation Computers</u> Those computers that use discrete, solid state, or hybrid solid state components, whose mode of operation is asynchronous, and whose characteristic designs are communications oriented (multiple bus). Software for second generation computers primarily is a multi-programming mode with limited (if any) time sharing features. Characteristic design for second generation

computer software is oriented primarily around multi system usages. The SDS 900 series computers were given prime consideration in this study.

Third Generation Computers - Those computers that use monolithic integrated circuits, operate in an asynchronous mode, and have a characteristic hardware design that is communications oriented. Software for third generation computers operates on a multi-system time sharing basis and has a characteristic design that uses real-time and multi-usage monitors.

- 10.2.4.5 <u>Evaluation</u> Of the three groups, first generation scored .26, second scored .63 and third scored .82 (See Figure 10.2-4 for breakdown).
- 10.2.4.6 <u>Recommended Design Approach</u> Based on this study, it is recommended that during Phase C the CDS computer selection be made from those computers that are in the Third Generation category. Some examples of computers that have been investigated and warrant further consideration are the GE 645, IBM 360-67, SDS Sigma 5 and 7, and EMR Advance 6130.
- 10.2.5 Trade Study-Technique for Automating Subsystem Test Sets
- 10.2.5.1 <u>Purpose and Scope</u> The purpose of this evaluation is to determine the optimum means of implementing automatic test sequence control and monitor for selected Capsule Bus subsystem test sets (SSTS).

Five approaches are considered: (1) hard-wired logic within each SSTS; (2) a central general purpose computer; (3) a "satellite" or small, individual automatic processor for each SSTS to be automated; (4) a punched-tape reader; and (5) a magnetic tape reader. The characteristics of each candidate, with required peripheral equipment, were evaluated for possible SSTS utilization at the subsystem vendor's plant, for systems integration and checkout at the contractors plant and for contingency checkout at KSC.

- 10.2.5.2 <u>Summary</u> The method for automating selected subsystem test set as determined by this trade study, is to utilize a small general purpose digital computer as the automatic processor.
- 10.2.5.3 <u>Functional and Technical Requirements</u> Several VOYAGER project and test implementation constraints were considered:

The SSTS must be capable of:

- o Performing all required test routines expeditiously, correctly and repeatably.
- o Providing self-test capability without test interruption for isolation of problems to OSE or related Capsule subsystem.

- o Interfacing with a general purpose computer for test sequence control or direction and data acquisition and display.
- 10.2.5.4 <u>Approaches and Significant Characteristics</u> Each of the five methods of automating the SSTS test sequence control and monitoring are listed with a brief explanation and the significant factors affecting the baseline choice.

<u>Hard-wired Logic</u> The controller provides a fixed program implemented by solid state, integrated circuits, electro-mechanical devices, or a hybrid design.

The significant factors are:

- o Lack of flexibility to changes in program.
- o Considerable engineering costs for circuit design.
- o Rapid test sequencing (except for electro-mechanical if included in the design).

<u>Central Computer</u> - Each automated SSTS time shares a common general purpose digital computer. Computer memory (size), speed, and instruction repertoire were the major constraints in the consideration of computer casts and performance characteristics. The significant factors are:

- o Excellent performance and ability.
- o Reasonable hardware costs.
- o Software more complex due to integrating all routines into one program.
- o Does not provide automated SSTS operation when the subsystem test equipment and control computers are not in close physical proximity
- o Self-tests are easily implemented.

<u>Satellite Computer</u> - Each automated **SSTS** has, integral to the subsystem test set, a small digital computer for test sequence control and monitoring. The significant factors are:

- o Flexibility for independent SSTS operation.
- o Relatively low costs.
- o Slower memory cycle and execution speed than larger computers, but adequate for application.
- o Permits simpler programming than required for a central computer.
- o Self-tests easily implemented due to random access memory.

<u>Punched Tape Reader</u> - A tape reader as an integral part of the SSTS to provide control and monitoring functions automatically. Both optical and mechanical tape readers have been considered. The significant factors are:

- o Lowest cost of the five methods considered.
- o Lowest reliability.

- o Most applicable to fixed sequence programs rather than random sequences.
- o Comparatively slower and noisier than other 'approaches.

<u>Magnetic Tape Reader</u> - Each SSTS contains its own magnetic tape reader for test automation. The significant factors are:

- o Speed is adequate for SSTS application.
- o Flexible for independent SSTS operation.
- o Overall performance is about average.
- o Moderately expensive.
- 10.2.5.5 <u>Recommended Approach</u> A satellite computer for each automated SSTS is the recommended approach for automating test sequence control and monitoring. Figure 10.2-5 summarizes the study results.

Specific performance details, capacity, costs and availability of small computers are the subject of an intensive study to be conducted during Phase C prior to final hardware selection.

- 10.3 SUPPORTING ANALYSIS In addition to the previous trade studies, supporting analyses are provided for the following major concepts: (1) STC automation, and (2) Launch Pad Propellant Dump Capabilities.
- 10.3.1 System Test Complex (STC) Automation Concept Four candidate STC automation concepts were considered (1) Mariner C, (2) Saturn IV-B Automatic Checkout System (ACS), (3) Apollo Acceptance Checkout Equipment (ACE) and (4) McDonnell Phase B STC. The Phase B STC Automation concept, described in Part D, Section 4.3, has been selected as the present baseline. The rationale for this selection is discussed in the following paragraphs.

Mariner C - This concept was rejected because:

- o The Flight Capsule STC requires automatic test sequencing and data evaluation because of the large number of parameters, testing of multiple systems, complex interfaces, and the need for continuity and repeatability of test history. The Mariner C employs only automated data evaluation, and does not possess the test sequence repeatability required.
- o The Mariner C approach requires direct analog access to the flight subsystem test connectors for system level testing. When the Flight Capsule is enclosed in the sterilization canister, this becomes impractical.

<u>Saturn IV-B ACS</u> - This concept was rejected because:

o It's limited display capability makes it incompatible with the VOYAGER Flight Capsule requirements for monitoring and test parameter readout.

CDS COMPUTER SELECTION

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- o The ACS does not employ a remote digital data link and consequently must be located within 2000 feet of the vehicle. This is incompatible with STC control of the Flight Capsule at the ESF and on-pad at KSC.
- o The ACS is not compatible with STC mobility constraints.

<u>Apollo ACE</u> - This concept is compatible with most of the Capsule system test requirements but is not recommended because:

- o The ACE is not configured to be easily transported between test sites.
- o The use of ACE for support of both Apollo and VOYAGER presents schedule conflicts for the 1973 launch.
- o ACE requires some major redesigns of the test data link (TM interleaver and relay-decoder module), and replacement of the rate RCM de-interleaver/decommutator with a low data rate Telemetry Command Processor (TCP).

Because the ACE system is operational at KSC, and fulfills many of the requirements for VOYAGER systems test, it is considered a candidate for further study. The concept of a Capsule Bus System (CBS) Test Complex which conducts system level test without subsystem test set integration, is particularly compatible with the use of ACE.

McDonnell Phase B STC - This approach has been selected because:

- o It offers maximum compliance to the constraints, is cost-effective, provides operational flexibility, and minimizes equipment duplication.
- o It provides maximum adaptability and growth potential for; (1) integration of the CBS, SLS, and ESP system test complexes into one, and (2) expanded future missions requirements.
- o It is the smallest physical configuration of all those studied, thus the most mobile, and requires less space in the integrated control room.
- 10.3.2 <u>Propellant Deservice Capabilities</u> The selected approach is to provide propellant deservice and canister purge capabilities at the launch pad. This is accomplished by attaching the deservice and purge equipment to the Capsule Bus (CB) propulsion subsystem via hoses attached at the canister mold line. (Sterility is maintained by using a burst diaphram in the propellant line). Upon receipt of a hazardous condition alarm from the Hazard Alarm and Monitor System a deservice and purge sequence can be initiated from the launch pad, STC or LCC.

Selection of this concept was made after analyzing the impact of a propellant leak if deservicing capabilities were not provided. While the probability of a propellant leak occurring at the launch pad is low, the potentially catastrophic results make it mandatory to provide for deservicing prior to demating and/or handling of the Flight Capsule.

The propellants used in the Capsule Bus (CB) are highly toxic, corrosive and hypergolic with organic materials. A leak is a serious safety hazzard to both operating personnel and equipment and could result in an explosion, fire or corrosive distruction of the flight system. The problem is aggravated by the time required to disassemble the Planetary Vehicle (PV) and return the CB to the Explosive Safe Facility (ESF) for deservicing.

Two alternatives are available for making the connections required to accomplish deservicing at the launch pad, The first approach requires a door in PV shroud to provide access to manual connections on the CB mold line. This approach provides deservice capabilities only until the Mobile Service Structure is moved away. The second method is to interface the system through a fly-away umbilical at the PV shroud mold line. This approach provides deservice capabilities up to lift off. Further study is required to evaluate the interface problems versus the need for launch pad deservicing.

- 10.4 ALTERNATIVE INTEGRATION CONCEPT The baseline integration approach used in the preceding sections of Part D, has isolated the support requirements for each system and established a point of reference for objective integration of OSE functions when the systems configuration and allocation of technical responsibility is firmly established. In order to provide a preliminary insight into the ultimate effect of OSE integration upon Capsule Bus System OSE, we have included the following study of an alternative integration concept that is based on sharing of common OSE functions by the CBS, SLS, and ESP contractors.
- 10.4.1 <u>Summary</u> The alternative integration approach (maximum OSE sharing) can result in a total equipment and space reduction of approximately 35% in the System Test Complex (STC) and 20% in the Subsystem Test Area.
- 10.4.2 <u>Identification of Shared and Common OSE</u> Based on the similarity of test and OSE functions, the primary candidates for equipment sharing are identified below.
 - o <u>Telemetry & Command Processor (TCP)</u> The TCP computer used in the STC is identical to those used in the Deep Space Network (DSN). If it is decided to replace the DSN computer with third generation computers, containing multisystem time sharing programming capabilities, a single TCP computer will be capable of telemetry processing for the CBS, SLS, and ESP. A reduction from three computers to one can be realized.
 - o <u>Computer Data System (CDS)</u> Two separate CDS's (computer plus peripheral equipment) have been identified; one for the CBS and one for the SLS.

- For integrated systems test (at CB factory & KSC) the SLS computer requirements could be incorporated into a single CDS by sharing the Capsule Bus Contractor'scentral processing unit and memory and adding an SLS multiplexer input/output processor and magnetic tape recorder. The combined CDS would represent a 35 to 40% reduction in equipment requirements over separate CDS's.
- System Test Complex (STC) The Test Director Console, Voice Communications System, Timing Distribution System, Recording Groups, and Ground Data Transmission System (GDTS) generate similar requirements for all three contractors in support of integrated systems tests at the factory and KSC. The recording group shows a possible 50% reduction in requirements by using a common central recording group for the integrated CBS/SLS/ESP. Of the remaining STC equipment, a major savings can be realized by common (CB/SL/EP) use of the GDTS in which a 65% reduction in data lines and 25% reduction in test command equipment is possible. The other STC equipment requirements would reduce by approximately 10%.
- o <u>Subsystem Test Equipment (SSTE)</u> A reduction in quantities of subsystem test set (SSTS) equipment can be realized if the ESP requirements are combined with either the CBS or SLS contractor requirements. The ESP/CBS combination is recommended because of the commonality of their telecommunication (TCM) subsystems. The following equipment savings are possible with this approach: Power SSTS 35%, Sequencer 35%, TCM 20%, Thermal Control 35%, and Pyrotechnic 35%. This represents a total reduction of approximately 11 racks of SSTS and two automatic processors associated with the sequencer and TCM SSTS's.